DREDGED MATERIAL RESEARCH PROGRAM

CONTRACT REPORT D-75-5

LANDSCAPE CONCEPT DEVELOPMENT FOR CONFINED DREDGED MATERIAL SITES

by

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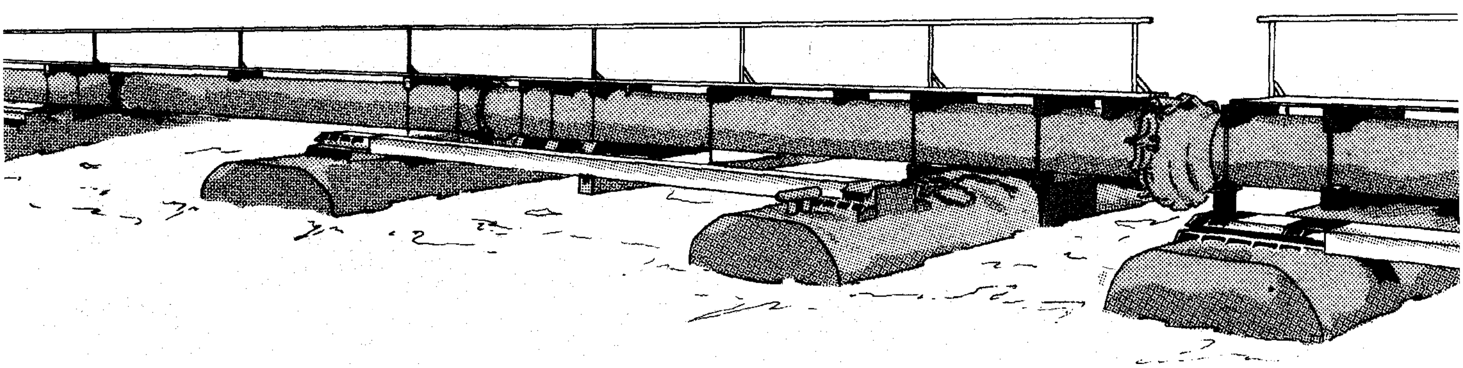
December 1975

Final Report



Prepared for Environmental Effects Laboratory
U.-S. Army Engineer Waterways Experiment Station
P. 0. Box 631, Vicksburg, Miss. 39180

Under Contract No. DACW39-74-C-0104
(DMRP Work Unit No. 5E01)

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION. CORPS OF ENGINEERS
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IN REPLY REFER TO: WESYV

31 December 1975

SUBJECT: Transmittal of Contract Report D-75-5

TO: All Report Recipients

1. The contract report transmitted herewith represents the results of one of the research efforts (work units) initiated to date as part of Task 2C (Containment Area Operation Research) of the Corps of Engineers' Dredged Material Research Program (DMRP). Task 2C is included as part of the Disposal Operations Project of the DMRP, which, among other considerations, includes research into various ways of improving the efficiency and acceptability of facilities for confining dredged material on land.

2. Confining dredged material on land is a relatively recent disposal alternative to which practically no specific design or construction improvement investigations, much less applied research, have been addressed. Being a form of waste-product disposal, dredged material placement on land has seldom been evaluated on other than purely economic grounds with emphasis nearly always on lowest possible cost. There has been a dramatic increase in the last several years in the amount of land disposal necessitated by confining dredged material classified as polluted. Attention necessarily is directed more and more toward the environmental consequences of this disposal alternative as well as to sociopolitical issues.

3. DMRP work units in progress are investigating improved facility design and construction and concepts for increasing facility capacities for both economic and environmental protection purposes. However, the total picture would be incomplete without considering methods of improving the appearance of facilities. To this end, the investigation reported herein was accomplished under contract with Roy Mann Associates, Inc. This study is considered a step leading to the implementation of improved planning, operation, and management practices emphasizing aesthetics.

4. This study reviews the principles and practices of confined disposal area operations and associated constraints and potentials for landscape

development. The study also documents landscape techniques directly applicable to the development of containment areas. Finally, a synthesis of information desired from the study was used in the development of landscaping guidance that can serve as an aid in planning, design, operation, and management of containment areas. It was concluded from the study that landscape development, if considered in the earliest project stages, can aid planners and engineers in achieving effective resolution of aesthetic problems and site reuse questions while accomplishing dredged material disposal objectives in full.

G. H. HILT
Colonel, Corps of Engineers
Director

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Contract Report D-75-5	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): LANDSCAPE CONCEPT DEVELOPMENT FOR CONFINED DREDGED MATERIAL SITES	5. TYPE OF REPORT & PERIOD COVERED: Final report
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Roy Mann, William A. Niering, Robert Sabbatini, Peter Wells	8. CONTRACT OR GRANT NUMBER(s): DACW39-74-C-0104 (DMRP Work Unit No. 5E01)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Roy Mann Associates, Inc. 180 Franklin Street Cambridge, Mass. 02139	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: U. S. Army Engineer Waterways Experiment Station Environmental Effects Laboratory P. O. Box 631, Vicksburg, Miss. 39180	12. REPORT DATE: December 1975
	13. NUMBER OF PAGES: 169
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Disposal areas
Dredged material disposal
Landscaping

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Confined dredged material disposal (CDMD) facilities have long been recognized as environmentally problematic for a number of physical, chemical, biological, and aesthetic reasons. The specific problem area of the aesthetic development of CDMD facilities is one that has received insufficient attention to date. The purpose of this study was to provide guidance for landscape development of CDMD sites. The approach of this study has been to: (1) examine the principle and practices of CDMD operations and the associated constraints (Continued)

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20. ABSTRACT (Continued)

and potentials to landscape development, through a review of the literature, and to extend knowledge through field reconnaissance and data gathering in selected Corps Districts and from other sources of scientific and technical information; (2) to document landscape techniques directly applicable to the development of CDMD facilities, including those techniques abstracted from research of analogous facilities; and (3) to synthesize the information derived from the first two steps into appropriate landscape development guidance that can serve as an aid in the planning and design of CDMD sites. Landscape development, if considered in the earliest project stages, can aid CDMD planners and engineers in achieving effective resolution of aesthetic problems and site reuse questions while accomplishing dredged material disposal objectives in full

PREFACE

This report presents the results of an investigation entitled "Landscape Concept Development for Confined Dredged Material Sites." The study was conducted as part of the Corps of Engineers Dredged Material Research Program (DMRP). The DMRP is sponsored by the Office, Chief of Engineers,and is assigned to the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, under the Environmental Effects Laboratory (EEL).

The study was funded under contract No. DACW39-74-C-0104 with Roy Mann Associates, Inc., Cambridge, Massachusetts. The contract was directed by Roy Mann, principal investigator, with the assistance of research associates Robert Sabbatini and Peter Wells. Howard C. Ris, Jr.,provided editorial assistance. During the course of this study site visits were conducted to the Great Lakes, Atlantic, Gulf and Pacific coasts U.S. Army Corps of Engineers District offices. In addition, requests were distributed to all Districts as well as to state agencies to obtain information dealing with natural or induced vegetation at CDMD facilities. Assisting in the preparation of the plant lists, under the guidance of Dr. William A. Niering, were Michele M. McKay and Sara Schneeberg of Roy Mann Associates, and Carolyn Weymouthe and Cheryl Foote of the Department of Botany, Connecticut College, New London, Connecticut.

Technical advice on earth preparation and plant establishment techniques was provided by Martin E. Weeks, Professor of Soil Science, University of Massachusetts; John M. Zak, Associate Professor of Agronomy, Plan and Soil Science Department, University of Massachusetts; Robert N. Morehouse, District Conservationist, U.S. Soil Conservation Service, Acton, Massachusetts; and Ralph H. Goodno, Community Resource Development Specialist, Massachusetts Cooperative Extension Service, Danvers, Massachusetts. Preparation of the manuscript was conducted by Susan Tucker Yaro and Elizabeth Bouche.

The contract was monitored by Ms. Jean Hunt and Dr. Luther

Holloway under the supervision of Dr. Roger T. Saucier, Charles C. Calhoun, Jr., and CPT William C. Allanach, Jr., all personnel assigned to the DMRP. The Director of WES during the course of this contract was COL G. H. Hilt, and the Technical Director was Mr. F. R. Brown. The Chief of EEL was Dr. John Harrison.

INTRODUCTION

The disposal methods employed in dredging operations have long been recognized as environmentally problematic for a number of physical, chemical, biological, and aesthetic reasons. In particular, the confined disposal method has received increasing attention and opposition from the general public with regard to aesthetic factors. Reasons for these aesthetic dissatisfactions include: the unnatural appearance of the disposal materials and retention structures, the great size of the areas covered, visual incompatibilities with adjacent natural and man-made environments, disturbing odors, visible turbidity of the adjacent waters resulting from suspension of dredged material, interference with existing and proposed land-use patterns, and a number of other intangible effects, such as the public connotation of confined dredged material disposal (CDMD) facilities as being derelict lands.

For these and other reasons, the Corps of Engineers has commissioned a number of research studies. This study is a component of the Dredged Material Research Program (DMRP). The DMRP is sponsored by the Office of the Chief of Engineers and is under assignment to the U.S. Army Waterways Experiment Station (WES), Vicksburg, Mississippi. The objective of this program is to provide information on the environmental impacts of dredging and dredged material disposal operations and to develop acceptable technical, environmental, and economic methods of dredging and disposal.

This study is coordinated under Task 2C, Containment Area Operation Research, the purpose of which is to create new and improved methods for the operation and management of CDMD sites. Several other areas of research within the DMRP are of interest to this study. These include but are not limited to the contracts commissioned under the following tasks: 2A, Upland and Marsh Disposal Environmental Impacts; 4A, Artificial Marsh and Island Creation; 4B, Habitat Development Research; 4D, Products Research; 5A, Dredged Material Densification; 5C, Disposal Area Reuse Research; and 5D, Disposal Area Land-Use Concepts.

CONVERSION FACTORS, BRITISH TO METRIC (SI) UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
yards	0.9144	meters
miles (U.S. statute)	1.609344	kilometers
miles (U.S. nautical)	1.852	kilometers
square inches	6.4516	square centimeters
square feet	0.092903	square meters
square yards	0.836127	square meters
square miles	2.58999	square kilometers
acres	4046.856	square meters
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The purpose of this study was to aid personnel of the Army Corps of Engineers in the landscape development of CDMD facilities. The study was approached first through a comprehensive review of literature on the operation of CDMD facilities. Knowledge of operations thus obtained was augmented by interviewing personnel and visiting disposal sites at the following selected Corps Districts: Philadelphia, Pennsylvania; Norfolk, Virginia, (Craney Island); Charleston, South Carolina, (Daniel Island, Drum Island); New Orleans, Louisiana; Galveston, Texas, (Pelican Island, Pasadena Site #5 and #6); Mobile, Alabama; Buffalo, New York, (Times Beach Site #2); Detroit, Michigan, (Grassy Island, Mud Island); Portland, Oregon. Data were requested of all Corps Districts and selected state agencies as to the adaptability of vegetation at existing disposal sites. Analysis was then applied to determine the constraints to landscape development inherent in CDMD facility operations. Landscape architectural modes and civil works analogous to CDMD sites were reviewed to identify applicable principles and techniques of landform modification and vegetative management. Landscape development concepts were synthesized from the analysis and screened for technical, economic, and environmental feasibility. Finally, concept and technical guidelines were developed and plant lists of known and potential dredged material adaptive species were compiled.

This report is therefore essentially divided into three parts. Part I reviews the state-of-the-art in the design, construction, maintenance, and operation of confined dredged material disposal facilities for the purpose of identifying the engineering constraints and variables relevant to landscape development. Part II presents a general discussion of the principles and practices of the profession of landscape architecture as they relate to the landscape development of CDMD facilities. Part III synthesizes appropriate landscape architectural design, planting, and construction technique concepts with the constraints and variables identified in Part I in an illustrated format suitable for use by Corps of Engineers personnel and consultants responsible for the landscape development of CDMD facilities.

A CDMD facility can and should be effective in a functional and aesthetic sense. Through a program of development carefully coordinated with engineers and landscape architects, CDMD sites can become integral and acceptable components of the existing landscape, environmentally and aesthetically. Although many recommendations and alternatives applicable to the landscape development of CDMD sites are dealt with in depth in ensuing sections, two principles merit emphasis here.

1. A CDMD facility should not be treated as a separate entity, but should reflect in its design a consideration for the present and future patterns of adjacent land use and land form.

2. The landscape development of a CDMD facility should be planned on an equal level and in concert with the engineering and functional requirements of the facility.

Aesthetic inputs into any project development need not and should not be a hindrance to the functioning of the facility. Landscape development of CDMD sites can aid in the functional operation of the facilities and contribute to improved acceptability in the eyes of the public.

PART I: EXISTING CDMD DESIGN AND CONSTRUCTION CONCEPTS - CONSTRAINTS AND VARIABLES FOR LANDSCAPE DEVELOPMENT

A. INTRODUCTION

The purpose of Part I is to present a concise summary of the pertinent concepts related to the design and construction of CDMD sites in order to define how these concepts will constrain or enhance potential landscape development of the sites. The material is sub-divided into three major sections: planning considerations, engineering considerations, and operation and maintenance of CDMD facilities. Within each section, constraints and/or variables related to landscape development are identified by means of verbal and graphic explanation.

B. PLANNING CONSIDERATIONS

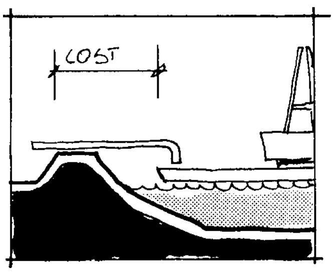
1. General

To date, the dredging contractor, and to some degree the Corps, is generally responsible for: a) selecting disposal sites for dredging projects; b) securing public ownership of the sites or obtaining easements to allow temporary use of the sites for disposal operations; c) designing and constructing containment facilities; and d) filling the sites with dredged material. The Corps' responsibility derives from statutory obligations, from internal Corps directives, and from contractual agreements that the Corps may enter into with private owners, contractors, or other public agencies.

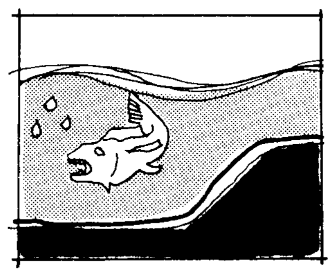
Other agencies and groups are increasingly involved in the Planning Process, particularly since public and private groups are becoming increasingly concerned about the environmental problems associated with CDMD projects. The questions of which sites to select for CDMD facilities and of how to determine future uses of the sites necessitate coordination with local public agencies and other interest groups.

2. Site Selection

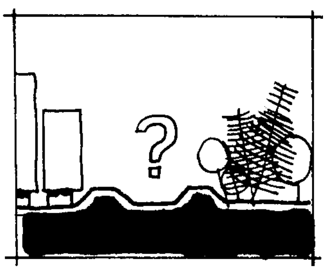
Site selection should carefully consider economic and environmental factors, social and aesthetic concerns, and the initial and long-range relationship between anticipated site uses and adjacent land uses. Economic considerations require the selection of a site close to the source of the dredging operations to minimize transportation and construction costs. Environmental considerations necessitate the selection of locations where natural ecosystems will not be damaged and where adjacent human settlements will not be adversely affected by disposal operations. Land-use considerations require locations to be found that will be consistent with local community plans and development objectives, state land-use or coastal zone plans, environmental impact assessment requirements, and Federal permit system and other review requirements.



Function of distance

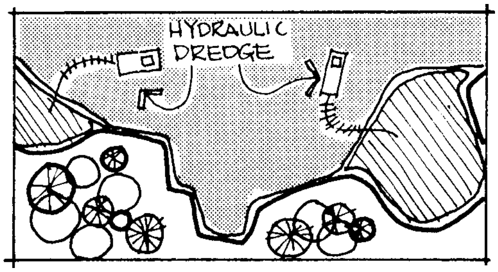


Protection of resources



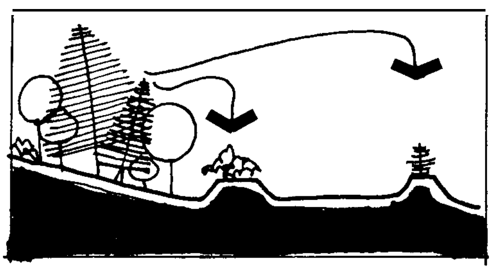
Proper land-use decisions

In the future, it is likely that greater emphasis will be placed on selecting fewer but larger sites. Sites may also be located farther from the sources of the dredged material because of environmental considerations, improved technology, or the lack of available sites in proximity to the dredging area. Where large sites are still available, remote from population centers and fragile ecosystems but close to the rivers or harbors where maintenance dredging is needed, conventional transporting and filling practices can be used. Where more remote sites must be used, long-distance piping or hauling may be required.



Analysis of the relation of the proposed CDMD facility to the surrounding landscape in the planning phase will help in the determination of:

- *Land Uses*
- *Site Configuration*
- *Earth Forms*
- *Environmental Safeguards*



Analysis of the existing vegetation surrounding the proposed CDMD site will help in the selection of plants which are suitable to the area. Native species will revegetate most easily.

3. **Ownership of Sites**

Project sites can be secured by the Corps; by a public project sponsor, such as a city, town, or port authority; or by a private contractor. Sites can either be purchased or leased by a public agency or be secured from private owners as easements for temporary use. In the latter case, owners can place restrictions on the use of the site, such as specifying the maximum height to which the dredged material may be dumped.

In such cases where Federal or state regulation prohibit open-water dumping of contaminated dredged material (e.g. EPA prohibition of open-water dumping in the Great Lakes), the Corps may require state and local sponsor agencies to obtain appropriate sites and provide containment facilities.

In any case, the public or private owner should be consulted with regard to land reuse objectives and community and aesthetic concerns. In the event that costs for landscape development are borne in whole or in part by the owner, the necessity for such consultation will be obvious. The desirability of constructive discussion with site owners and local planners concerning community and aesthetic objectives should also be apparent.

4. Interim and Future Uses of Sites

In planning for site utilization, concurrent and future use of the site must be considered. In the early history (20-30 years ago) of CDMD projects, sites were generally selected and developed without much consideration for potential future uses; it was generally assumed that project sites would remain derelict land unless a private owner could generate constructive reuse plans for the area. Now, increasing attention is being placed on future uses of the site. Some feasible uses include wildlife preserves, public recreation areas, agricultural areas, livestock grazing areas, and industrial parks. Marsh habitats can also be restored in many areas where marshland has been lost as a result of natural causes or human development. New marshland can be also created in suitable areas. In the future, as land for urban needs becomes more and more scarce, CDMD sites may be used for a greater variety of purposes and intensities of use.

Also, coordinated concurrent or interim use of CDMD facilities should be considered, particularly where maintenance dredging operations occur at lengthy intervals. Temporary camping and trailer park uses are conceivable, as are grazing pastures for livestock or plant nurseries.

5. Responsibility for Construction and Operation of Sites

The Corps must receive authorization from Congress for the planning and execution of all major projects.

Once a site is selected, ownership or agreement for use of the site is secured and future use commitments are made, then design and construction of the retention structures can proceed. The design process is clearly becoming a primary responsibility of the Corps since in the past, where this responsibility has been delegated to private contractors or local sponsors, the results have often proved to be unsatisfactory. The Corps has the technical expertise and considerable experience in the preparation of design plans and specifications for containment facility construction; when engineers, landscape architects, and environmental or resource planners can be coordinated in a joint effort, results can be achieved of an unquestionable quality.

In those Corps Districts where equipment and manpower are available to perform actual construction, the need for private contractors may not arise. Ordinarily, such Corps manpower is not available and contractors perform this work under Corps supervision. In either case, site planning considerations and future landscape development should be considered during the preplanning stage and incorporated into the plans and specifications for CDMD site construction.

6. Environmental Review

The National Environmental Policy Act (NEPA) requires environmental impact statements to be filed for Federal projects that induce adverse effects on the environment. Corps guidelines under NEPA require the preparation of environmental impact statements (EIS) for both proposed and existing dredged material disposal projects. These must be distributed to public agencies for comment.

The NEPA also authorizes the EPA to monitor the pollution content of dredged material. Monitoring of effluent quality is the responsibility of state or regional agencies.

Other legislation applicable to Corps dredged material containment projects include such legislation as the 1970 River and Harbor Act (PL 91-611), which restricted many Great Lakes disposal operations to confined sites, where polluted material was present.

7. Public Review and Response to Projects

People traveling, living, working, or participating in recreation activities in the vicinity of CDMD facilities are becoming increasingly sensitive to CDMD facility appearance. A primary public concern is the possibility of dike failure, which can cause flooding, turbidity, and the release of toxic pollutants. Other problems that can occur include erosion, excessive dust, disturbing odor, increased mosquito breeding, project unsightliness, disruption of ecological systems, nonconforming future uses of the disposal site, and decreases in the property values of adjacent lands (Harrison and Chisholm, 1974). Although many of these sources of public or community dissatisfaction cannot be easily remedied by facility design, imaginative and feasible landscape development can, in many instances, ameliorate visual problems, improve recreation and amenity reuse, and increase public acceptability.

8. Corps Directives and Guidance on Landscape Development and Funding

The U.S. Army Corps of Engineers' policy strongly supports aesthetic protection on civil works projects. Personnel involved with landscape development of a CDMD facility should be well acquainted with the two Corps documents that deal with this area of concern: ER 1165-2-2, "Consideration of Aesthetic Values in Water Resource Development," (1967) and EM 1110-2-38, "Environmental Quality in Design of Civil Works Projects" (1971). Engineering manuals (EM) are intended to aid design engineers in their design responsibilities on various projects. Engineering regulations (ER) are written in regards to Federal legislation applicable to U.S. Army Corps of Engineer work. Both are intended as guidance documents rather than as fixed directives relative to project design (Harrison and Chisholm, 1974).

ER 1165-2-2 "requires that full consideration be given aesthetic factors in the planning and carrying out of the Civil Works Program." General policy instructs that Corps personnel "will consider both the economic and aesthetic consequences of its recommendations and actions," and "where it is found possible to improve natural conditions at a cost warranted by the aesthetic values created, the enhancement of natural beauty may be made a purpose of the project."

To date, funding for aesthetic development related to recreation at Corps projects is authorized under PL 89-72, the Federal Water Project Recreation Act. Under the act, the Federal government will split recreationaldevelopmentcosts with the State or other non-Federal agency involved on a 50%-50% cost-sharing basis. Costs for aesthetic development not relating to recreation or other economic benefits are assumed in total by the Federal government. By relating the aesthetic development of CDMD sites to future public recreation use, it may be possible to allocate a certain portion of landscape development costs to local sponsors and other local and State agencies. It is also important to realize that aesthetic development need not be thought of as an additive cost to a project, but rather as an integral part of any project in that it can promote public acceptance, aid in achieving such engineering requirements as erosion protection, and enhance programs for proposed future uses.

EM 1110-z-38 deals with planning policies for environmental quality in design and emphasizes the maintenance and improvement of the environment from the initiation of a project: "Incorporating environmental quality in project design involves considerably more than a superficial treatment of aesthetics. It involves designing with nature in all of its dimensions--ecological, visual, and human-cultural--rather than against or onto it."

Since proper input and coordination with project engineering, construction, operation, and maintenance is essential, landscape development concepts and design guidance must be introduced to the design process when project planning is initiated. Project staff should also include qualified landscape architects, botanists, and other suitably trained professionals, or outside expertise should be secured when such capabilities are not present.

C. ENGINEERING CONSIDERATIONS

1. Introduction

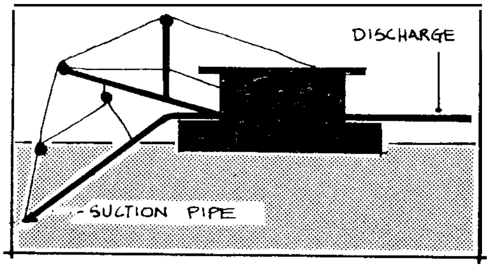
Of primary concern in assessing the potential for landscape development of CDMD sites are the limitations imposed by engineering factors affecting the functioning of the containment facility. Since the major function of the design of a CDMD facility is to confine the dredged material to a particular area, the degree to which landscape development concepts can be employed to enhance the appearance and future use of the site will be dependent on the extent to which the concepts can be applied without interfering with the functioning of the facility. Thus it is important for the design professional involved with formulating a landscape development plan to be familiar with the engineering constraints and variables associated with the functioning of a CDMD facility. These factors are discussed in the following sections.

2. Dredging Techniques

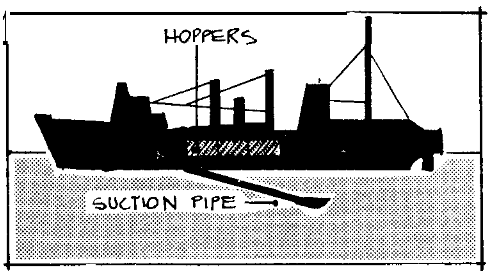
While the dredging operation itself will not directly affect the landscape development of the CDMD facility, the differing types of dredged material excavated by the various dredging techniques and the transport methods used to carry the material from the excavation site to the disposal area will pose certain constraints for earth-forming and vegetation planting. (Mechanically dredged material is generally transported via scow or barge to the CDMD sites). These constraints are discussed in Section C-5 below (Disposal Area Problems). A brief listing of the various types of machinery is given here, however, to familiarize the reader with the pertinent techniques.

a. Hydraulic dredges

Hydraulic dredges may be either of two types:



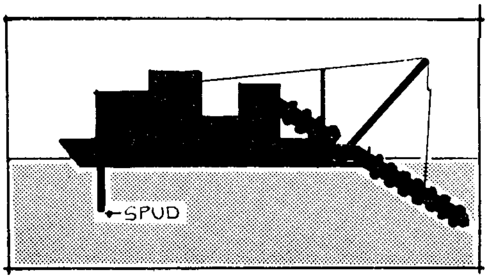
Pipeline: The pipeline dredge is the most versatile and commonly used type of dredge plant. Large volumes of material (up to 5000 cubic yards/hour depending on pump size and intake pipe diameter)can be handled using a cutterhead and suction head which sucks the sediment material from the bottom. The pipeline method can be used to dredge continuously at depths of up to 100 feet. The material is transported to the disposal site via pipeline.



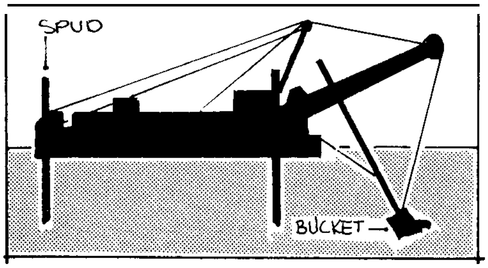
Hopper: The hopper dredge is a self-propelled vessel that uses a drag to suck sediment from the bottom. The dredged material is then loaded into hoppers and dumped into a rehandling basin or pumped to the CDMD site. Hopper dredging is limited to depths of 60 to 70 feet. Dredging activities must be discontinued while the dredged material is transported to the disposal site.

b. Mechanical dredges

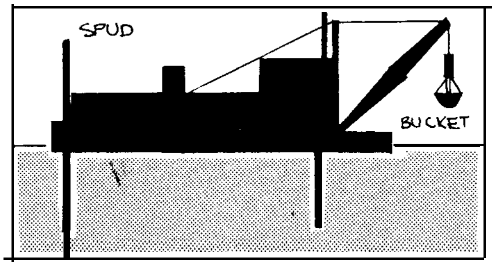
There are three types of mechanical dredges:



Ladder: The ladder dredge uses a continuous chain of buckets on a pivot arm. The dredger is mounted on a barge and usually cannot operate in depths greater than 40 feet.



Dipper: The dipper dredge consists of a power shovel mounted on a barge and is particularly useful for excavating hard bottom material, in depths less than 60 feet.



Bucket: The bucket dredge consists of a crane-operated bucket (clamshell, orange-peel, or dragline) mounted on a barge. It can operate in depths up to 100 feet.

3. Retention Structures

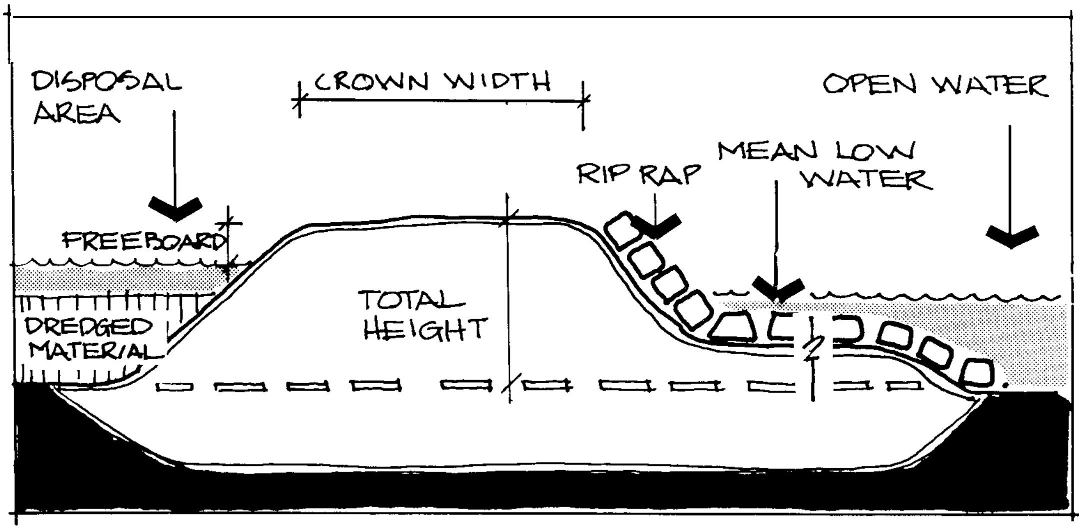
Since the dredged material to be disposed of at a confined site is usually in the form of a slurry, a retention structure or dike is commonly used to confine the material to the site. In addition, the retention structure functions to direct the water runoff from the dredged material to the point or points where the water is discharged to the adjacent water body, thus facilitating the drying out of the site. Obviously then, the design and construction of the retention structure will significantly determine the configuration of the dredged material disposal site and its subsequent aesthetic appearance.

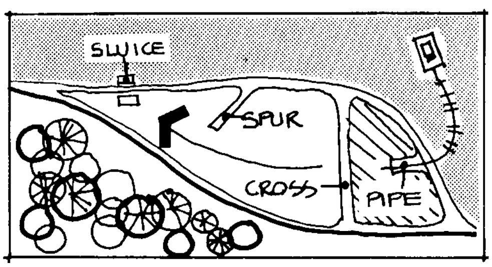
On the following cross-section diagram given in Figure 1, a few of the key terms associated with dike construction are illustrated.

a. Types of dikes

The types of dikes which can be used for retention purposes will differ primarily in their construction material and not in their form. Dikes are often built in stages: the initial dike and subsequent incremental dikes that increase the height of the original structure as the height of the mass of disposed material rises. Since

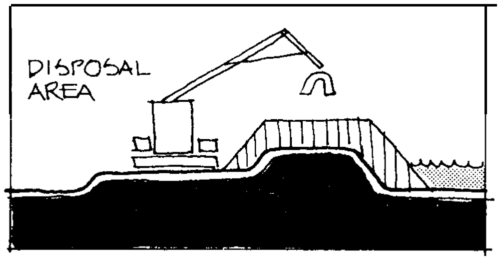
Figure: 1 **Retention Structure Terminology**



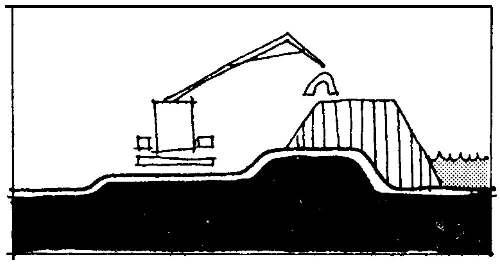


the filling operations may continue for many years (in some cases for as many as 20 or 25), it is not usually necessary to construct the retention structure to its final height at the outset. In addition, the dike and foundation will gain in shear strength over time, as the material consolidates. However, in the situation where adequate construction material is initially available, it may be more economical to build the initial retention structure to its final height and long-range capacity since the machinery and manpower will be on site at the outset.

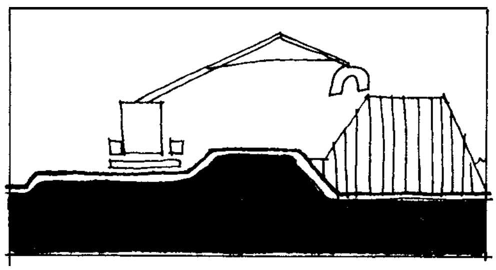
Incremental dikes may be of cast form or of stepped form as shown in the following illustrations.



a. *Cast dike placed directly on top of initial dike*

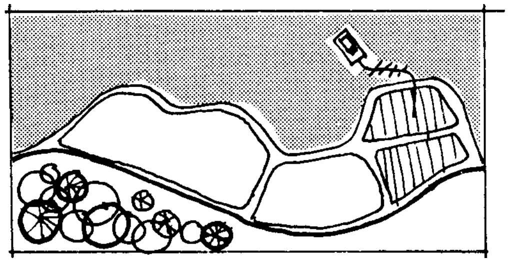


b. *Minimum stepped dike placed on top of initial dike but stepped back from the face of the initial dike*

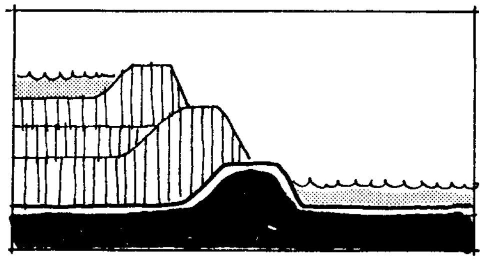


c. *Maximum stepped dike is separated from the initial dike by a flat berm or a small drainage channel*

With regard to the implications for landscape development, the final shape or configuration of the disposal area will be significantly influenced by the design of the initial dike, since the initial dike will provide the foundation for subsequent retention structures. The incremental dikes, on the other hand, will by their design affect significantly the visible height and silhouette appearance of the disposal site.



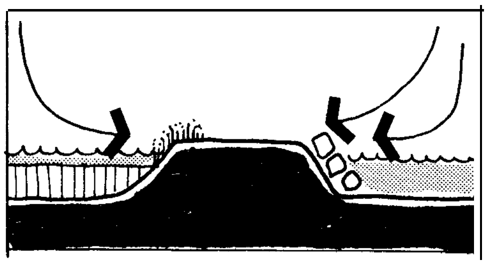
Design of the initial dike determines the final configuration of the disposal site.



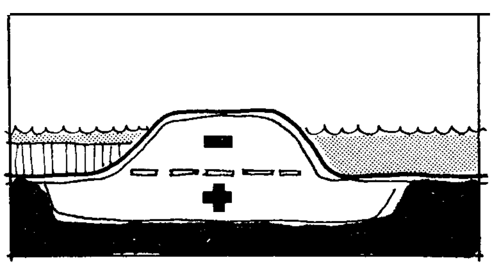
Design of incremental dikes affect the visible height and silhouette of the disposal. site.

b. **Structural criteria**

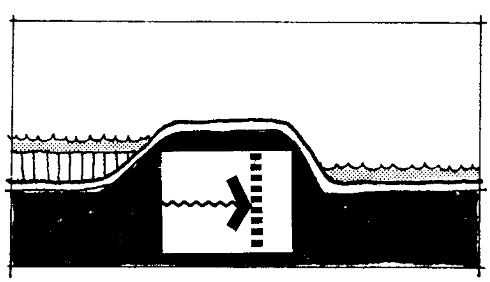
The structural criteria diagrammatically illustrated below must be satisfied in dike construction and will constrain land- scape development by affecting the dimensions of the dike and the types of construction materials used.



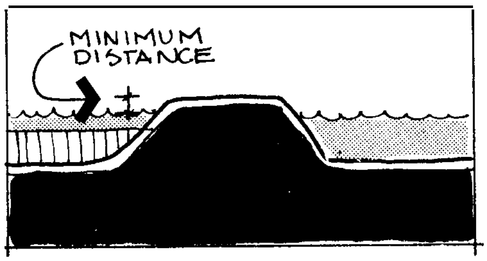
a. *The slopes of the dikes must be stable under all foreseeable conditions and circumstances for the life of the disposal facility*



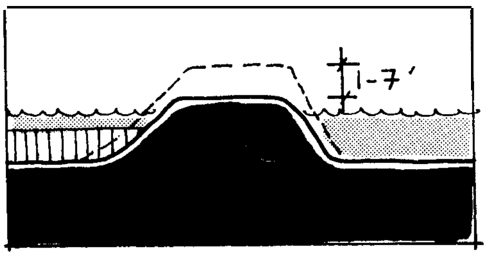
b. *The dike must not place excessive stresses on the foundation and must be stable against sliding*



c. *Seepage flow of water from inside to outside of the dike must be controlled to prevent sloughing of the outer slope of the dike*



d. The freeboard must be great enough to prevent "overtopping" erosion by waves from inside the dike



e. Unless overbuilt, a dike may settle and require placement of additional material. This may preclude initial earth-forming and planting of dikes.

c. **Foundation conditions**

Ideally, a firm foundation should be established before the dike is placed so that the stability of the dike can be ensured However, in most locations where CDMD facilities are sited, the underlying material is generally soft and susceptible to subsidence under the extreme loads of the dike material and the dredged material. To make the dike stable would require removing the material and replacing it with granular material. This is obviously expensive and is often difficult to do. Therefore, settling of the dike material must be accepted and accommodated.

A weak foundation condition many times requires the construction of a wide-based dike section. Even so, the dike material can be expected to consolidate considerably. In subsoil deposits of clay and silt, consolidation occurs slowly, but will occur nonetheless. In some cases the placement of dike foundation material on a soft existing material will actually cause the poorer material to be displaced, thus establishing a firmer foundation. This method reduces the width of base required.

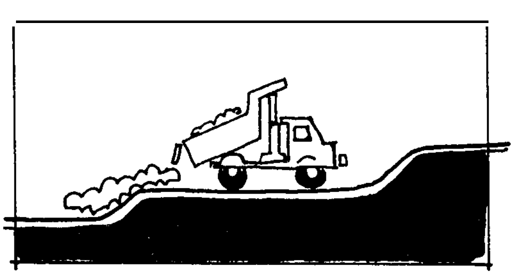
d. Types of material used

Dike materials should be stable. This generally means the use of a granular material, either stone or gravel, or material

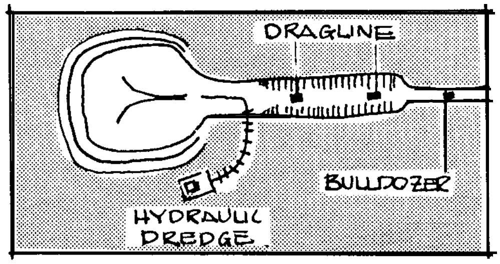
low in organic content. In a few cases this requires importing a granular material to the site from an off-site source, since most of the native soils that could be borrowed at the site (generally riparian) are silty and not ideal for dike construction. Clay, when properly compacted, is often acceptable. In some cases it may be possible to obtain gravel or bedrock materials from deep river-bottom excavations, which will facilitate transport to the site by boats. In some cases an inorganic material is used, such as in the Buffalo District where slag is available from nearby steel mills (Murphy and Zeigler, 1974). Generally an initial dredging operation involves the removal of virgin material, which characteristically is a stronger building material than the usually silty materials dredged from subsequent maintenance operations. In most cases, however, the dike material used is available at the site and therefore Can impose constraints on the vegetation used.

e. Construction techniques

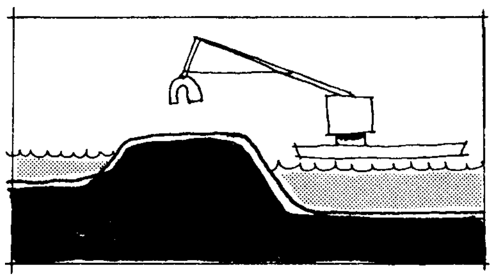
There are three basic techniques for constructing the dike as illustrated in the following diagrams. The determining factors for selecting one technique over another, or in combination, are the type of fill material, the souce of the material, and, of course, the economics of the situation, including the transport distance and the availability and costs of various equipment and manpower.



a. *Rolled or dumped fill:* *This type of dike is employed where a land borrow source of acceptable quality is available within reasonable hauling distance of the site*



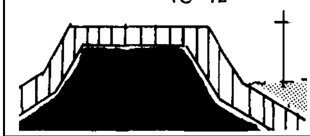
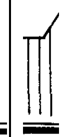
b. *Hydraulic fill:* The ideal situation for construction of a diposal area in the water is that in which suitable borrow material for a hydraulic fill dike is encountered inside the disposal area.



c. *Dragline fill:* When materials suitable for dike construction are available along the dike alignment, dike construction by barge-mounted dragline is often the most economical method of construction. The best materials for this construction are sand and gravel.

Table 1 summarizes the construction methods used to build the various types of dikes and lists several aesthetic and landscape development constraints.

Table: 1 Incremental Retention Structure Construction

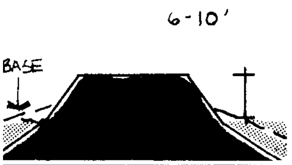
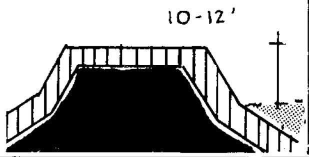
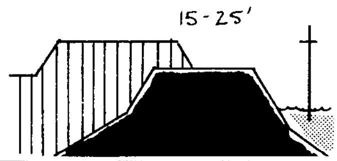
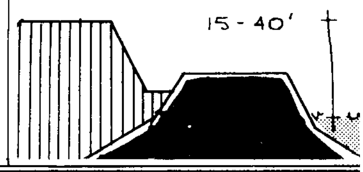
	DIKE BASE	PRIMARY DIKE	CAST INCREMENT	SE
	2-8' 	b-10' 	10-12' 	
PREDOMINANT FUNCTIONS	Base of dike in open water	Formed to increase height and improve cross-section of dike base.	Use of materials of low stability to increase dike height.	Usec and are atec uall init cast
CONSTRUCTION METHOD[2]				
Hydraulic Placement	Dredged material (DM) spread in open water along axis of retention structure (RS).	NA (not applicable)	N4	
Rolled or Dumped Fill (by vehicles)	!!A	Vehicles/equipment manipulate and form RS.	Vehicles/equipment manipulate and form RS.	Vehi sele
Dragline	NA	Dragline manipulates and forms RS.	Dragline manipulates and forms RS.	Drac RS.
CHARACTERISTIC SHEAR[2] STRENGTH OF DEPOSITED MATERIALS	Poor; material placed and attains natural slope.	Poor-good; engineered form increases stability.	Poor. Materials placed, self-attained slopes.	Gooc
ECONOMICS OF[3] METHOD	NA	NA	Generally least expensive to attain given height.	Gene mode ial
AESTHETICS AND GENERAL CONSTRAINTS	Barren but natural in appearance other than geometric/non-natural process form.	Barren in appearance. Slope facings may detract visually (see Table 4).	Barren in appearance; generally not protected by riprap or other extensive coverings. Low height, therefore, minimal visual effect.	Heic line witt may dent step
LANDSCAPE DEVELOPMENT CONSTRAINTS	Initial construction stage, no landscape development possible	Vehicular access, if provided, constrains usable space for aesthetic improvements. If it is an incremental RS, planting and aesthetic improvements may be temporary/delayed.	Since last increment for RS of poor quality DM, RS can be planted. Minimal vehicular access.	Init Vehi uppe tior

[1] Interviews, District personnel (refer to Introduction)

*Murphy and Ziegler, 1974.

[3] Interviews, District personnel

on Structure Construction

PRIMARY DIKE	CAST INCREMENT	SECONDARY DIKE	SECONDARY DIKE (WITH SETBACK)
			
Formed to increase height and improve cross-section of dike base.	Use of materials of low stability to increase dike height.	Used where added materials and foundation conditions arc highly stable. Associated with inland sites. Usually constructed after initial RS in lieu of the cast RS.	Used where added materials and foundation conditions are highly stable and greater heights are needed. Associated with inland site.
NA (not applicable)	NA	NA	NA
Vehicles/equipment manipulate and form RS.	Vehicles/equipment manipulate and form RS.	Vehicles/equipment transport selected DM for addition to RS.	Vehicles/equipment transport selected DM for addition to RS.
Dragline manipulates and forms RS.	Dragline manipulates and forms RS.	Dragline raises DM and shapes RS.	Dragline raises DM and shapes RS.
Poor-good; engineered form increases stability.	Poor'. Materials placed, self-attained slopes.	Good.	Good.
NA	Generally least expensive to attain given height.	Generally inexpensive; low to moderate quantities of material are used.	Generally expensive; large quantities of [material are used.
Barren in appearance. Slope facings may detract visually (see Table 4).	Barren in appearance; generally not protected by riprap or other extensive coverings. Low height, therefore, minimal visual effect.	Height predominates. Views and lines of site may be blocked without careful planning. Height may seem imposing in rural residential areas unless it is stepped back sufficiently.	Height predominates, minimized however by increased setback. Geometric shape less predominant due to setback.
Vehicular access, if provided, constrains usable space for aesthetic improvements. If it is an incremental RS, planting and aesthetic improvements may be temporary/delayed.	Since last increment for RS of poor quality DM, RS can be planted. Minimal vehicular access.	Initial RS can be planted. Vehicular access may move to upper RS crown, freeing additional areas.	Greater area can be planted. Planting can visually minimize effect of height and geometric shape.

f. Embankment slopes and crown widths

The slope of the dike embankment is dependent on: the foundation conditions, the embankment material used, the type of construction technique employed, and the necessity for additional erosion protection devices. For example, a weak foundation condition will necessitate the construction of a flat slope dike with a wide foundation base; in some cases exterior dike slopes as flat as 30H on 1V may be required. As a general rule, if the dike is composed of firm material, a steeper slope can be used. Retention structure slopes are normally limited to 3H on 1V. If the slope is to be protected from erosion by riprap or other materials, the slope can be made steeper.

A 2H on 1V slope is generally accepted as the steepest slope that permits machine placement of the riprap. In addition, the stability of the riprap is questionable on steeper slopes (Department of Army, in preparation).

Table 2 gives the slopes that the different types of material require to withstand the effects of erosion.

Table 2 Optimal Slope Design

Erosion source:	rain, wind	rain, wind	+ waves	+ waves*
Cover	bare	vegetated	riprap	bare/vegetated
sand & silt	6H on 1V max.** 6H on 1V opt.	2 or 3H on 1V max. 4H on 1V opt.	2H on 1V max. 4H on 1V opt.	15H on 1V max. 15H on 1V opt.
clays	2H on 1V max. 4H on 1V opt.	1H on 1V max. 3H on 1V opt.	2H on 1V max. 3H on 1V opt.	15H on 1V max. 15H on 1V opt.

* Department of the Army, 1971, EM1110-2-28

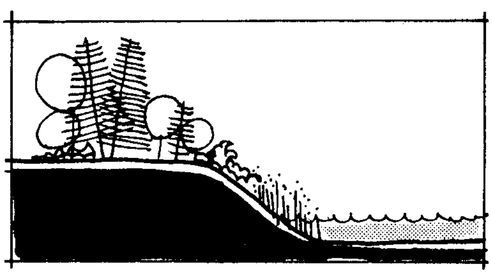
** Shallower slopes are more desirable to ensure success of the earth form, planting, and maintenance; max: maximum slope which withstands erosion; opt: optimum desirable slope.

The slope of the dike may be varied: where poor foundation conditions must be accommodated a shallow slope below the water line may be necessitated; while above the water line, a steeper riprap slope can be constructed.

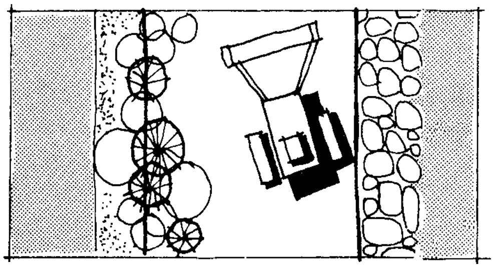
The width of the crowns of the dike can also vary greatly, depending on the design requirements of the dike. If the dike is to serve as a base for an incremental dike, it should be sufficiently wide, approximately six to eight feet, to accommodate the new material. If the dike is to accommodate operational and maintenance vehicles (dragline cranes, bulldozers, or trucks), the crown width should be increased to approximately 12 to 14 feet.

As shown below, the slopes and crown widths of the dikes will constrain the planting of vegetation and subsequent uses of the dike.

Care should be taken in the placement of vegetation during the operation of the CDMD facility so as not to jeopardize the integrity of the retention structure. It should be noted that insufficient research has been conducted to date on the need for root-free zones on exterior dikes.



A steep dike slope may require special planting techniques for vegetation



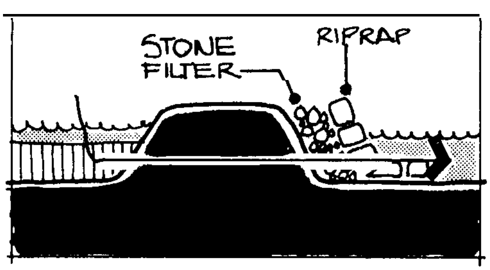
Crown widths determine the type and placement of planting which can occur, especially if vehicles have to move along the top of the dike

g. **Water release devices**

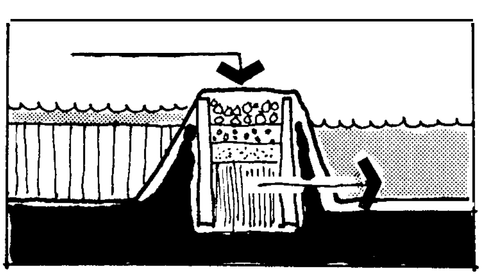
Devices for releasing the excess water from the disposal operation are integrally related to the retention structure. Since water passing over the dike would cause erosion, several sluicing devices have been developed to let the water pass out of the disposal area. These include outfall pipes, siphons, drop inlet sluices, and box sluices or flumes. There are various supplementary appurtenances that can accompany these basic types, such as silting basins, Y or E - gates, outlet channels, and oil skimmers. The relationship of the sluice gates to the discharge points and internal structures are explained in Section 6: Disposal Area Problems.

A discussion of the sluice types and accompanying appurtenances is not particularly relevant to landscaping enhancement of retention structures, since these devices are small and relatively inconspicuous compared to the total length and mass of the dike and disposal area. The water quality of the effluent is a significant problem, but again not directly relevant to this study.

Another technique for removing water from a site allows the water to seep through the dike. This will occur naturally to some extent, especially when granular materials comprise the dike section. However, to maximize the efficiency of seepage dewatering and to prevent erosion due to sloughing, it may be desirable to use one of the filtering mechanisms illustrated below.



Dike filter: *A stone blanket comprised of sand, gravel, and stone or a filter blanket and stone on the exterior side of the dike to filter effluent as the water seeps through the dike.*



Vertical sand filter: *Steel cells filled with a granular material to filter effluent; this structure can be incorporated into an earth dike*

4. Retention Structure Physical Problems

The problems that cause dike failure or damage can be summarized under three categories: 1) foundation failures; 2) surface erosion; and 3) seepage damage. In addition, certain visual problems may result from the construction of retention structures, such as the obstruction of views from certain vantage points and the intrusion of man-made elements with a mechanical appearance into the natural landscape.

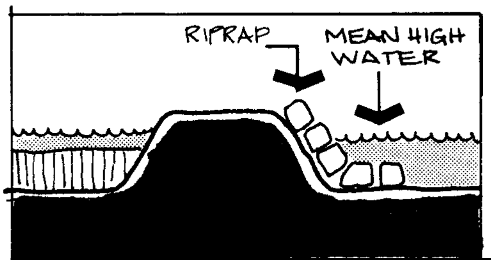
a. Foundation failures

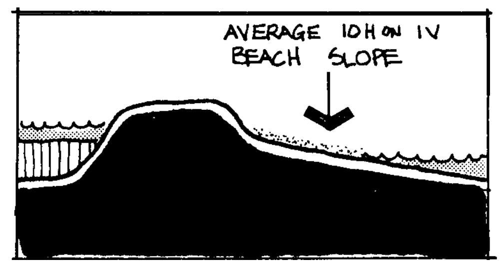
Structural damage to dikes is often the result of foundation failures. A dike may sink into a soft, organic foundation or may spread due to the sliding of the foundation along soft clay strata or sandy seams. The remedies for these problems are dependent upon treatment of the foundation materials or a priori careful analysis of the foundation bed and the design of a suitable dike section, and as such can be little influenced by landscaping design.

b. Surface erosion

Wave action is the primary cause of dike erosion. Where dikes are located within or directly adjacent to water bodies, waves can erode the exterior embankments of the dike. On all kinds of disposal facilities, regardless of the location, the water impounded in the interior of the dike can erode the inside face of the dike and often the entire dike due to overtopping. Rain, ice, and, to some extent wind forces can also cause erosion on dike surfaces. In some cases, erosion of the dike may occur near the sluicing device, especially when the discharge point is too close to the outfall pier or weir.

There are several possible engineering remedies to correct these problems of erosion. On the exterior face of the dike, the chief techniques call for armored protection (the use of riprapping) or the creation of a sand-filled beach at the foot of the dike in water. The riprapping should extend from a point several feet below mean low water to an elevation at least several feet above mean high water, ideally meeting the protected crown. Its thickness will vary according to the degree of protection required. A sand beach should be constructed so that it maintains an average slope of 10H on 1V.





Riprapping may also be used on the interior face of the dike in large facilities. Impervisou material such as polyethelene sheeting may also be used for interior slope protection. It may also be possible to stabilize the top surface of the dike by an impervious material; asphaltic concrete, which also serves as a roadway surface, is an obvious possibility. However, the use of such material, as with riprap, is considered an extreme measure to be used only when initial dikes are constructed in open water and thus exposed to the extreme forces of wind and waves (sometimes to hurricane forces).

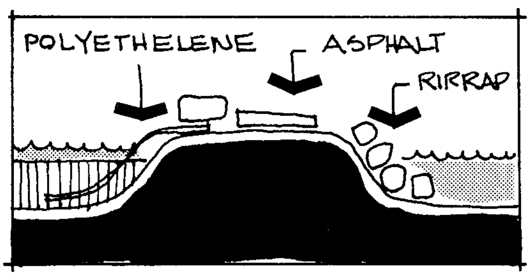
The use of vegetation as an erosion-control device is a logical option to consider, either by itself or in conjunction with the above engineering solutions. This technique is used by some Corps Districts to a limited degree. The use of vegetation for erosion control, as well as other equally important uses, is discussed in Part II.

C. Seepage damage

Seepage, or passage of water through the dike, can cause dike failure or damage by piping, an interior eroding of the dike material caused by the movement of water and resulting in the loss of the final particles, or by sloughing off, a sliding of materials away from the outer edge of the dike.

The release of pollutants, including salt to the surrounding area is another potential problem related to seepage. The polluted or saline material can detrimentally affect surrounding vegetation as well as animal life.

Solutions to seepage include providing an impermeable barrier either in the dike or on the inside surface of the dike. Another possibility is the use of dike filters, which allow water to pass through but which filter out pollutants in particulate form and prevent the erosive effects of seepage.



Artifical seepage barriers, riprap, polyethelene, and asphalt, all restrict planting or use areas

A summary of the physical problems associated with retention structures in relation to constraints on landscape development, earth-forming, and planting is given in Table 3.

d. Visual problems

Visual problems associated with the dike (as distinguished from the entire retention area) are significant to persons viewing the facility from the ground plane, i.e., from the adjacent shoreline or from boats on the water. The dike, when it is part of an island or peninsular facility, is a large physical obstruction to views across the body of water in which it lies. The artificial characteristics of the dike, namely its rigidity if linear, its hard surface quality if covered with riprap, and its disproportionate massiveness, can disrupt the visual harmony of the landscape. Methods of reducing such visual disruptions are discussed more

Table: 3 Retention Structure Problems and Remedies

PROBLEMS		REMEDIES		
RETENTION STRUCTURE PROBLEMS	CONTRIBUTING FACTORS	BASIC REMEDIES	CRITICAL MEASURES	
Foundation failures	Soft bottom, mat break-through or sliding failure	Reconstruction	Replacement of foundation and RS.	
Erosion	Waves Wind Rain Ice	Asphalt	Should cover entire crown and meet riprap to offset increased wave runup and possible overtopping	Extreme initial RS on to extr
	Waves Wind Rain Ice	Riprap, tetrapods, precast concrete revetments	Should extend Sufficiently above and below water line and be of sufficient thick-ness to withstand dynamic forces	Expensi
	Waves Wind Rain	Polyethelene sheeting (interior slope only)	Should be well secured	Tempora ates wi of inst sun's r niovemen this pr
	Waves	Sand Beach	Should average 10H on 1V slope from MHW to MLW lines	Natural elimina Placed
	Waves Wind Rain Ice	Vegetation	Should achieve a dense growth of grasses and other vegetation in minimum time possible.	Natural
Seepage/ Bleeding	Excessive per-meability or trapping of water and sub-sequent washout of RS section.	Polyethelene sheeting	Should be secured with sand bags or other means on interior slope prior to disposal operation.	Tempora until d suffici

nedies

	AESTHETIC AND GENERAL CONSTRAINTS	LANDSCAPE DEVELOPMENT CONSTRAINTS EARTH-FORMING	PLANTING
ation	NA	Height and slope of base limited by the strength characteristics of the foundation material.	NA
crown ffset and	Extremely expensive; used in initial construction of RS on large projects subject to extreme exposure.	Height and slope of RS limited according to method of erosion control employed; riprap and precase concrete allow greater heights. Intricate land forms may accentuate erosion process.	Placement prohibits vegetation until secondary RS is built.
ciently r line thick- namic	Expensive solution		Placement prohibits plantings.
ed	Temporary. Unsually deteriorates within 6 months to 1 year of installation. Action of sun's rays, rodents, wind, and movement of DM will speed up this process.		Polyethelene sheeting does' not allow immediate planting (on interior face of RS); may generally disintegrate within 6 months to 1 year.
n lV W lines.	Natural appearance. May eliminate need for riprap. Placed on outside of RS only.		Vegetation will only grow above MLW in high wave energy areas.
se d other m time	Natural appearance.		Possibletimelaq between end of construction period and establishment of an effective cover.
th sand on to	Temporary, but generally lasts until dike permeability is sufficiently reduced by fines.	Seepage must be controlled before earth-forming.	Polyethelene sheeting does not allow immediate planting (on interior face of RS); may generally disintegrate within 6 months to 1 year. Salts may leach out and destroy surrounding vegetation where material is dredged from saltwater bottom and placed in freshwater surroundings.

fully in Part III of this report. However a brief summary focusing on the characteristics of dike facings which affect visual quality is presented in Table 4.

5. Disposal Area

As stated earlier, "the principal objective of a dredged material containment facility is the retention of solid particles and the release of clean water to natural water." (Murphy and Zeigler,, 1974). Thus a potential land mass, the disposal area, is created as a result of the retention of the dredged material. Characteristics of the disposal area and methods for dispersing the dredged material within disposal sites are discussed in subsequent sections as they relate to constraints and variables affecting landscape development.

a. Shape, size, and height of the disposal area

The volume of material to be dredged and the number and frequency of times a site is to be filled will significantly affect the resultant shape, size, and height of the disposal area. When calculating the allowable volume and frequency of filling to occur at a disposal area, the type of foundation material already present at the CDMD site and the composition of the dredged material to be added must be analyzed to determine the amount of settlement, consolidation, and/or bulking that will occur. Certain other factors, such as the slurry discharge rate, the ponding time, and the rate of excess water runoff, will also influence the size and height of the disposal area (Murphy and Zeigler, 1974).

Generally, CDMD facilities are polygonal or follow convenient natural contours, primarily for ease of layout and construction. Where foundation materials are poor or structurally sound building material is scarce, the retention structure will be built along a natural deposit of solid material such as a low rise of land or a sandbar. In such cases,

Table 4 Visual Characteristics of CDMD Facility Components

SILHOUETTE
Consider lines of sight. Views from surrounding land and water areas determined important by surrounding inhabitants and from an on-site investigation should be preservedand enhanced where possible.

SHAPE
Consider the shape and form of the CDMD site in relation to the surrounding land forms: undeveloped natural/rural areas generally suggest curvilinear shapes; developed urban/industrial areas may suggest the use of more geometric forms or the intermittent use of curvilinear forms.

FACINGS	NEAR VIEW	FAR VIEW	RECREATIONAL USE CONSTRAINTS
Tetrapods/ Dolos	Highly rigid and artificial in form, 'light, and color. Used primarily in break-water construction.	Impact diminishes with distance, but color will stand out considerably.	Access to/from water edge diffi-cult.
Riprap	Rigid form unappealing, especially if used ex-tensively in natural area	Impact diminishes with distance.	Access to/from water edge difficult.
Precast Concrete Revetments	Hiyhly rigid, negative appearance when barren. Grid design dnd plant-iny may provide visual interest.	Impact diminishes with distance. Appearance will remain uni form over time.	Access to/from water edge can be accommodated.
Polyethelene Sheeting	Artificial appearance, especially if colored sheeting is used.	Usually visible; however, deteriora-tion will occur within 6 [months to 1 year of installa-tion. (Black color deteriorates less.) Impact diminishes with distance.	Prohibits immediate use of planting. Impact diminishes over time with disintegration of the material.
Dredged Material	May be compatible with existing shoreline appear-ance, but barren without protection. Erosion creates visual scars and unnatural contours.	Impact diminishes with distance.	Access should be controlled to minimize erosion.
Natural Vegetation	Compatible with existing shoreline appearance, but may establish unevenly resulting in a spotty appearance.	May produce desirable effect over the long term, but may be spotty.	Use restricted until vegetation is well estab-lished.
Induced Vegetation	Compatible, immediate effect. Regularly spaced plantings may result in negative effect; random pattern preferred.	Compatible immediate effect, especially if tall species are planted.	Use restricted until vegetation is well established

the confined disposal area takes on an irregular and curvilinear shape.

In order to avoid interference with normal water circulation, sediment transport, or salinity patterns in estuaries and other water bodies, disposal facilities must be carefully laid out with respect to currents and benthos.

The area1 size of disposal facilities is a function of the frequency of the filling operation; the surface area and the distance from the point of discharge to the point of exit should be great enough to allow the dredged material to settle out before it reaches the exterior of the facility. The size of facilities varies from as small as three acres (Alameda Creek in San Francisco Bay) to as large as 3500 acres (Sabine Lake in Galveston). Size, or course, is limited by the availability of space in the vicinity of dredging operations. Where alternate sites (inland or more distant water edge locations) are beyond feasibility, the facility must be increased in height to accommodate the volume of material to be disposed).

The initial and ultimate height of the disposal facility overall will depend on a number of factors including the volume of material to be dredged over the time span of operations, the requirements for a single or incremental dikes, the aesthetic compatibility of high disposal facilities with the surrounding natural and man-made environment, and future site use.

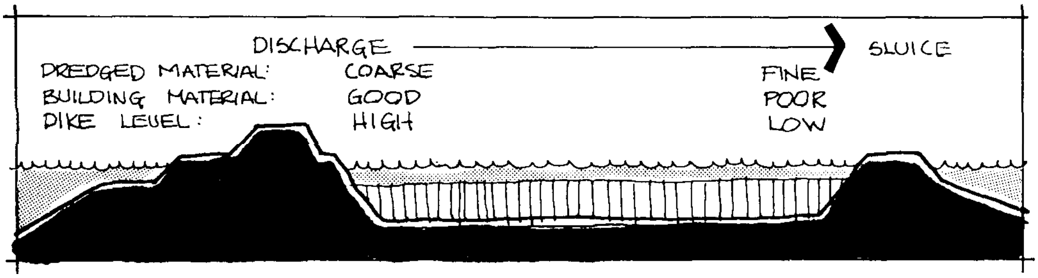
Although shape, size, and height can be modified only to a limited degree, the modifications that can be made may be significant in visual terms if appropriate guidelines are followed. Briefly, in terms of <u>size</u>, very large projects should preferably be subdivided into several smaller components; in terms of <u>shape</u>, natural contours should be followed or simulated, for both visual and functional (e.g. small harbor) purposes; and in terms of <u>height</u>, the silhouette of the upper elevations of disposal facilities should be varied, articulated with tree and shrub plantings to achieve aesthetic diversity. Depth above water table of disposed material within the facility will also help determine the types of vegetation which can adapt successfully.

b. Disposal methods

Hydraulic and mechanical methods are used to discharge the dredged material into the disposal area. By far the most common and efficient method for large-scale disposal into confined sites is by hydraulic means, i.e., pumping the slurry into the disposal area through pipes, located either above ground or buried underground and/or under water. The source of dredged material will usually be a pipeline dredge. Material pumped out of hopper dredges is common in some areas. A combination technique, which uses a rehandling basin (a deep-dredged pit in the water adjacent to the disposal site), allows the dredged material to be dumped from a variety of dredge types and dredging operations and subsequently pumped into the disposal site.

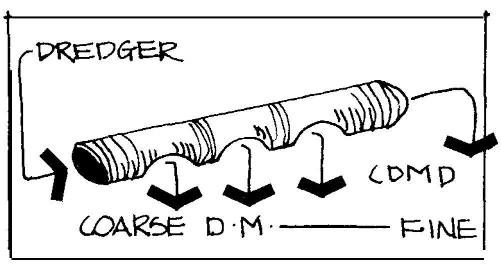
The hydraulic pumping method is useful for long-distance transport of the slurry. Pipeline distances of 7,000 to 10,000 feet are not uncommon with modern equipment. Distances of 5 miles have been traversed via piping and booster pumps in the Gulf Coast area, and various plans are under consideration by other Districts for longer distance piping.

The slurry which is pumped hydraulically into the disposal area is about 80% water and 20% solid material. The coarser materials settle out first, closer to the pipe outlet. The finer materials, silt and clay, remain in suspension in the slurry water pond and tend to settle out last, near the sluice (or they may also pass through the sluice, causing turbidity in the surrounding water).



Location of coarse vs. fine material varies along cross section of disposal area.

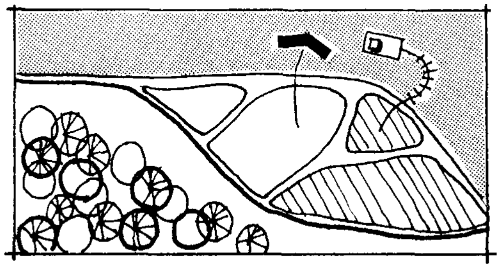
A bleedpipe may be used to reduce the velocity of the pumped material and settle out the coarse-grained materials. A diagrammatic illustration of the mechanism appears below.



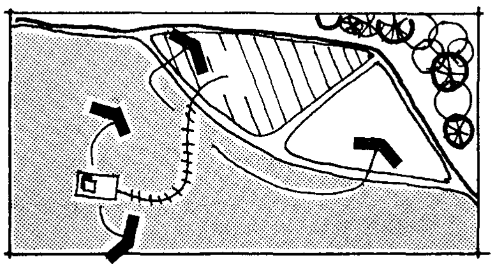
The bottom of the pipe is perforated to permit the coarse-grained material to settle out as the velocity of the slurry is decreased while rising to the elevated end of the pipe. If appropriately placed, such a mechanism may be usefu for reinforcing a dike with the coarse materials.

Mechanical methods of disposing of dredged material into contained sites include the use of dipper dredges, bucket dredges, and ladder dredges, which may be barge mounted or free standing, but these methods are commonly used only on smaller operations due to the limited capacity of such machines. They are also used where floating and/or submerged pipelines can interfere with shipping movements.

Table 5, Confined Disposal Operation Methods, lists these methods and the constraints and opportunities they impose on landscape development. The following two diagrams illustrate some of these concepts.



Hydraulic method provides greatest flexibility in disposal area shape. Compartmentalization will permit a selected portion of the CDMD site to be filled.



Hydraulic method allows CDMD facility to be a great distance from the dredge site.

C. **Characteristics of the material**

Dredged material can be categorized according to its major physical properties, including grain size, moisture content, and plasticity.

The material from the maintenance dredging operations of the Corps has been roughly divided into five grain-size groups: A) mud, clay, topsoil, shale; b) silt and sand mixed; C) sand, gravel, shell; D) organic muck, sludge, peat, municipal-industrial waste; and E) mixed. The sand and gravel category is the only coarse-grained dredged material and is therefore generally acceptable for fill where foundation support is required. The finer grained materials generally have high water content, and are therefore not very firm. Organic content can produce objectionable odors when disposed of on land.

The most plentiful quantity of dredged material in the United States is the silt and sand category: 51% of the 300 million cubic yards dredged annually in the United States are in this category. The next most plentiful type (27%) is the mud, clay, silt category (Group A). The third most plentiful (16%) is the coarser grained material, sand and gravel (Group C) (Boyd, et al., 1972).

Table: 5 Confined Disposal Operation Methods and Landsc

DISPOSAL METHOD	PRINCIPAL OPERATION	DREDGED MATERIAL CHARACTERISTIC	MAXIMUM ECONOMICAL DISTANCE TO DISPOSAL SITE, GENERAL COST CONSIDERATIONS	FLEXIBII DISPOSAI
PIPELINE DISPOSAL	Used universally except in areas of heavy navigation, e.g., harbors.	Slurry is generally 80% water, 20% solids.	5+ miles with the use of booster pumps; operations generally large-scale and cost efficient.	Continu(floatin(Point 0 varies station tiple/r(of acce: retenti((RS).
HOPPER DISPOSAL Direct pump-out or bottom dumping barge	Used principally in waters where pipelines would interfere with navigation.	Slurry is generally 80% water, 20% solids.	Slight limitations on distance. Slower and less continuous project executions. Economically suitable for small dredging projects.	Dredged containe a) place ling ba: ect pum RS th merged from a alongsic
MECHANICAL Dipper Clamshell Bucket (includes draglines)	Used principally on very small jobs and in areas unsuitable for pipeline of hopper disposal method.	Oversized debris: mud, clay, rocks. Low water content if transferred directly to CDMD site without use of scows for transfer (which require hydraulic slurrying and pump-out).	Slight limitations on distance. Slower and less continuous project execution. Economically suitable for small dredging projects.	Sedimen dredged and trar CDMD si ling bar

thods and Landscape Development Constraints

NOMICAL DISPOSAL AL COST TIONS	FLEXIBILITY OF DISPOSAL METHOD	PIPELINE PLACEMENT CONSTRAINTS	LANDSCAPE DEVELOPMENT CONSTRAINTS
n the use of s; operations rge-scale and nt.	Continuous operation, floating pipeline. Point of access varies from a fixed station(s) to multiple/random points of access along retention structure (RS).	**Fixed Access Point:** Controls placement of DM within the CDMD site with minimal disruption of the RS. **Multiple/Random Access Points:** a) Pipe laid directly over RS. Greatest possibility of disruption due to mechanics of pipeline placement	**Multiple Access Points:** Possible disruption of planting and landforms at various points if access points not controlled and planned into the CDMD site.
ations on dis- r and less con- ect executions. suitable for ng projects.	Dredged material contained in hopper: a) placed in rehandling basin, b) direct pump out into RS through submerged pipeline from a fixed point alongside CDMD site.	b) Spillbarge: minimal disruption of RS in multiple access point operation. Floats along outside of RS 20 ft height and maximum 250 ft. boom. Possibility of use within CDMD site which would increase flexibility of placement of DM.	**Fixed Access Point(s):** Least interference with plantings/landforms
ations on dis- er and less con- ect execution. suitable for ng projects.	Sediments are dredged into scows and transferred to CDMD site rehandling basin.	**Fixed Access Via Rehandling:** Allows greatest flexibility of placement of DM in that DM may be placed within the CDMD site at discretion of CDMD site operators.	

Table 6, Dredged Material Characteristics, illustrates some of the constraints to landscape development characteristic of the different dredged material types. A further discussion may be found in Part III of this report in the section dealing with implementation concepts.

d. Internal structures

There are several different kinds of retention structures or dikes that can be constructed within a disposal area. A spur dike is a long arm of raised material that is generally constructed perpendicular to the outer containment structure. It is attached to the outer dike at one end but terminates in the middle of the disposal area. It is generally used to direct the flow of the slurry after it is pumped into the disposal area; this helps to prevent channelization.

A cross dike is a spur dike that is extended so that it connects one side of the containment structure with another and thereby divides the disposal area into compartments; such compartmentalization induces settling out in localized points to hasten the settling process.

A pipe dike, which is a raised linear mound, is often constructed to support a pipe when the point of discharge of the slurry is somewhere in the center of the disposal area. Often pipes are branched-off within the disposal area, and gate valves are inserted at pipe junctions to shut off and open the flow of slurry as required.

6. Disposal Area Problems

Typical problems associated with the design and functioning of disposal areas are: too rapid or too slow release of the impounded water; excessive exposure to climatic elements; or visual disruptions. These are discussed below.

a. Water released too rapidly

Water that is released too rapidly from the discharge pipe during hydraulic filling operations will tend to dig a channel in the deposited dredged material and follow the shortest route to the sluice. This kind of internal erosion interferes with the normal settlement of the solid dredged material from the slurry. The basic technique for correcting this situation is to direct the slurry flow so that it forms a pond between the discharge pipe and the sluice. The flow of water is slowed and allows the suspended solids to settle out before they can enter the sluice and become discharged into the surrouding water. Another technique is to construct spur dikes to direct the flow of water or to act as baffles to the rapid flow of slurry.

b. Water released too slowly

Although the ponding function is necessary, it can become a detriment to the operation if the water is not released through the sluice or the dike filter after a reasonable length of time. This long-term ponding can cause the production of adverse odors or can prevent the establishment of vegetation in the dredged material area. Sometimes excessive rainwater aggravates this condition within a disposal facility. The basic remedy for this problem is to ensure that the sluices or other dewatering devices are working adequately. Sometimes it is simply a matter of adding additional sluices to a large disposal area when only one sluice is present. It may, however, become necessary to reschedule the pumping operation to prohibit further release of the dredged material until the pond level is diminished.

c. Exposure to the elements

The effects of wind are generally adverse since wind-blown

Table: 6 Dredged Material Characteristics and Landscape De

DREDGED MATERIAL TYPE[1]	PARTICLE SIZE	USA DISTRIBUTION[1]	SHEAR STRENGTH[1]	SUITABILITY AS FOUNDATION MATERIAL	SUI CONST
A. Mud, clay, silt, top-soil, shale	Colloidal to fine	27%	Poor with high water content	Poor to very poor	Poor
B. Silt, sand	Fine to coarse	51%	Poor to fair; variable water content	Good to poor	Very fairl
C. Sand, gravel	Coarse	16%	Good, large grained	Good	Reaso to ve
D. Peat, organic muck, fin sludge, muni cipal wastes	Fine; organic	6%	Poor with high water content	Not suitable	Not s
E. Mixed types	Variable		Variable	Variable	Varial

[1]Boyd, et al., 1972. Note that this is not a formal classification.

ape Development Constraints

SUITABILITY FOR CONSTRUCTING DIKES	DRAINAGE	AESTHETIC AND GENERAL CONSTRAINTS	LANDSCAPE DEVELOPMENT CONSTRAINTS
Poor stability	Slow	Cracking, rill formations and sloughing	High salt retention; 6 months to 1 year to leach out salts if at all. Shrinkage and cracking; unstable if water saturated
Very stable to fairly stable	Medium	Rill formation, but not as evident as in Type A	Most suitable type for larger vegetation species
Reasonably stable to very stable	Fast	May have barren appearance unless in formation resembling natural littoral land form	Poor fertility. Rapid drainage may promote excessive drought for some induced species
Not suitable	Slow	Objectionable odors; dark appearance; cracking, puddling.	Poor stability; high moisture content. Poor drainage; high organic content; high toxic and heavy metal content in many cases. Generally unsuitable for induced plants if not mixed with other DM types
Variable	Variable	Constraints vary. according to component types	Constraints vary according to component types

waves can cause erosion of the dike on the outside slope. If the disposal site is large enough, waves can be generated that may erode the interior slopes. Wind-induced waves can also increase the turbidity of the ponded water, while dust turbulence can be severe on dried-out sites. However, winds lower turbidity if their direction is against the direction of flow from the discharge point to the sluices. Prolonged exposure of the dredged material to the hot sun can create desiccation cracking on the exposed surface of silty, clayey dredged material. This is harmful in that breeding habitats for mosquitoes may be increased. On the other hand, the drying out of the material at greater depths will be hastened.

d. Adverse visual impact

In addition to the technical problems that may occur on disposal areas as described above, there may be other aesthetic problems. For instance, the repeated pumping of new dredged material on top of old dredged material on which vegetation has become established either kills the vegetation or covers it so that only the top branches of trees remain visible, resulting in a grotesque, unnatural appearance. Excessive ponding may result in vegetation kills.

Subsequently, the dead remains of trees reinforce the image of the CDMD as a derelict facility. Even desiccation cracks in a hard-baked surface create to some degree the image of a derelict area.

Perhaps of greater concern is the inhuman connotation of an extremely large and undifferentiated disposal area, especially if it is located next to an inhabited area. While a large facility may be efficient from an engineering point of view, it may be out of scale and therefore visually objectionable to people who have to live or work nearby or who come into contact with it during recreational pursuits.

D. OPERATION AND MAINTENANCE OF CDMD FACILITIES

The primary operational concern of a CDMD facility once it has been constructed initially is the maintenance of the dikes and the control of the location of the pipe used to pump the slurry. This pipe has to be moved to permit the efficient functioning of the disposal operation: namely, to maintain the proper ponding time and discharge rate.

Often the pipe is moved along the face of the dike, especially with the floating pipeline technique used in the Gulf Coast. The Great Lakes Districts generally utilize a method whereby the slurry enters the CDMD site at a fixed point, but the pipe within the dredqed material area is moved.

In the Galveston District, pipelines are often carried great distances across the land from the edge of the channels to the point of slurry discharge into a CDMD facility. At Pelican Island, in Galveston Bay, separate pipes pass on the surface of the land, but under a new roadway through culverts, to the disposal area. Permanent easements are usually provided. In either case, equipment is necessary to move the pipes at the disposal site itself. Generally a bulldozer is used for this operation.

Another operational concern is the future construction of incremental dikes or expansion of the site to increase the capacity of the facility. The technique used to construct the incremental dike must be anticipated, so that the equipment necessary to do the job can be accommodated. A dragline that moves along the initial dike or the inside toe of the dike on dredged material is usually required to build incremental dikes. A bulldozer or other earth-moving machine may also be required to shape the new secondary dike.

Another characteristic of the filling operation is its periodic nature. Rarely is this operation continuous throughout the year for any one disposal facility. There is generally not enough material from maintenance dredging operations in any District to warrant a year-round operation. Also, equipment is shared from one port or channel to another within a District, as in the Great Lakes ports where the hopper dredges make the rounds. At the mouth of the Mississippi River, the sedimentation process is seasonal (February to June), thus necessitating only seasonal dredging operations.

In many Districts, maintenance dredging is not necessarily performed each year. Therefore, there does not have to be continuous surveillance and maintenance of the components of the CDMD. Dikes and weirs must of course be maintained during the filling and dewatering operation, and the free board must be maintained. It is advisable to have periodic inspection of the facility to check the condition of the dredged material and equipment.

PART II: LANDSCAPE ARCHITECTURE METHODOLOGY

A. INTRODUCTION

The profession of landscape architecture has been and continues to be largely concerned with the design and analysis of inter-relationships between human elements and the environment. The following discussion briefly describes the principles and practices of landscape architecture as they relate to the development of CDMD facilities. A brief overview of the history of the profession is presented in Section B, followed by a discussion in Section C of the technical and design principles applicable to CDMD development. Section D, an Examination of Selected Analogous Facilities, further examines the application of landscape architectural practices to projects and operations similar to CDMD facilities.

B. OVERVIEW OF THE HISTORY AND RELEVANCE OF LANDSCAPE ARCHITECTURE

The pioneer builders of colonial America practiced the principles of landscape architecture by their use of indigenous materials for construction projects of all scales and by their understanding of the need to adapt their man-made structures with the landscape. Landscape architecture as a profession in America originated most notably with the planning, design, and construction of Central Park in New York City. Frederick Law Olmsted, along with his partner Calvert Vaux, designed this large open space for the benefit of the thousands of inhabitants of that crowded city. Their skilled effort met the diverse problems of engineering, horticulture, and design. They reduced the conflict between vehicular traffic and pedestrian movement through grade separation of the traffic flows in the park, and integrated the drainage and water-supply systems within the park design so as not to disrupt the visual and aesthetic unity of the park.

From this beginning, the efforts of landscape architecture have been advanced to meet present day challenges. For instance. the planning of highways, characteristically rectilinear in design and unyielding in layout, have slowly evolved to the scenic highways of today. Overpasses now take on sweeping curvilinear forms and the horizontal alignments of the roadways are sensitive to the landscape. Large-scale planting within the rights-of-way has helped to harmonize the road with the land. The design of the Merritt Parkway in Connecticut is one of the pioneering examples of how a vehicular parkway can be well integrated with the environment through which it passes.

The siting and design of utility installations and the renovation of gravel pits, sanitary landfills, and similar previously neglected projects are now a matter of concern to public agencies with regard to environmental and aesthetic considerations. There are good examples, particularly in England, where the challenge of moderating the impact of large power stations upon the landscape has been met. At Snowdownia National Park, for instance, the landscape design scheme was to accept the main bulk of a large power station but to take advantage of the natural ground configuration by emphasizing it with new grading, and to hide the ancillary equipment from public view (Lovejoy, 1973).

The problems concerning the design and maintenance of CDMD facilities are already being studied under the direction of the U.S. Army Corps of Engineers. The principles and techniques of landscape architecture can make a positive contribution to this effort.

C. EXAMINATION OF LANDSCAPE ARCHITECTURAL CONSIDERATIONS

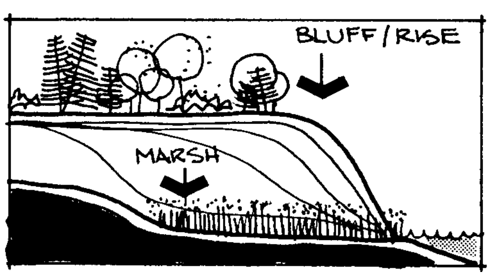
The landscape is a continuum of natural forms and structures, and any project that may modify the landscape should carefully consider the potential impact of introducing new man-made elements. A new facility should complement the environment it will occupy, visually as well as functionally.

The visual quality of a facility is its most discernible characteristic, particularly if the facility is to be sited on open land or water. Projects may well comply with the requirements of Federal and State laws and regulations with regard to biophysical factors and yet still be visually intrusive within the landscape. Project planning and design must confront this concern.

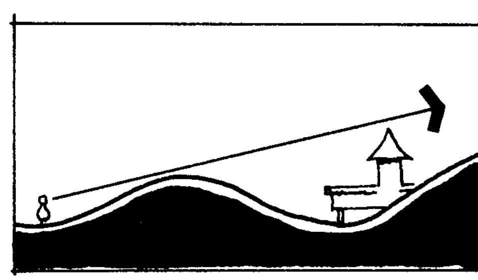
1. General Design Concepts

a. Land configuration

An important part of the design process is a consideration of land configuration. This includes concern for those factors that have shaped the land as it exists: the requirements of the intended use on the landform, alterations of the land configuration for adaptation to the intended use, and the creative balance that may be attained between the functional layout and aesthetic appearance. The form of a facility must not only be functional and visually interesting by itself, but also must be integrated into the formal context of the scale and character of the surrounding environment.



Each landform dictates different planning requirements



Earth-forming used to screen views

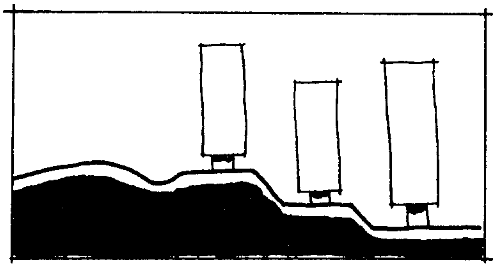
b. Three-dimensional earth forming

Earth forming has long been employed to screen views partially or fully or to muffle sounds. Earth can be built up to form enclosures or to create vantage points or can be excavated to form lakes and other desired depressions. Mounding can direct the flow of water, the direction and velocity of the wind, and the routes of people. If judiciously placed, mounds, berms, and earth forms, combined with plantings can screen undesired objects and reduce the apparent height and therefore the intrusiveness of some elements on the landscape.

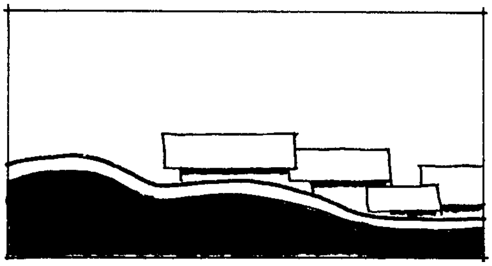
Grading is required as the final step of land preparation prior to planting. Its basic function is to restore land that has been modified during construction so that it conforms with the original landscape; the new earth forms must be blended in with the landform of the adjacent area. Grading is also necessary to provide positive drainage of surface water.

C. Siting of structures

Possibly the most important concern of landscape architecture is the placement of buildings or other structures on the land (or water) such that an aesthetic as well as ecological balance is maintained with the natural characteristics of the environment. Structures should be related to landforms, vegetation, and the other elements for practical and aesthetic reasons. A building should be located so that there is natural drainage away from the building, and so that the landform can screen the view of the more utilitarian parts of the building and accentuate desirable views. Similarly, buildings can be carefully located next to trees that can aide in climate control or screen the impact of dominant structures. Buildings and natural elements of the landscape should be treated together so that both are harmoniously related.



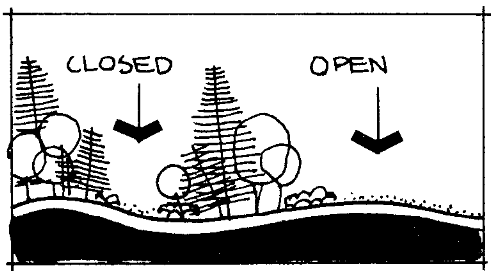
Buildings not related to natural landforms



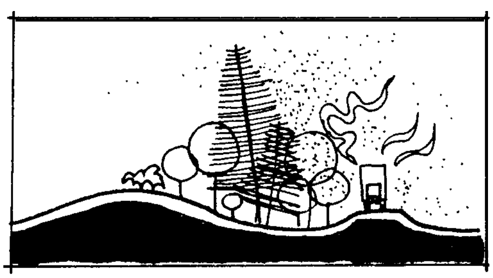
Buildings sympathetically related to natural landforms

d. Planting design

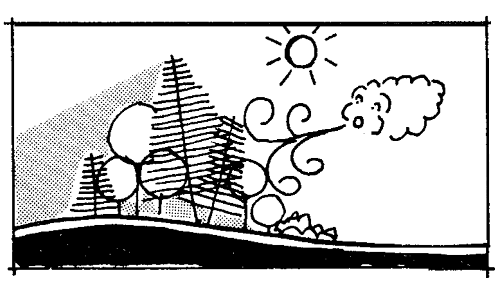
Planting is used for numerous reasons to solve a wide range of environmental problems: architectural, engineering, climatic, aesthetic, and conservation (Robinette, 1972). To do this effectively, the designer must have a working knowledge of plant characteristics, their individual functional roles, and the degree of effectiveness in performing these functions:



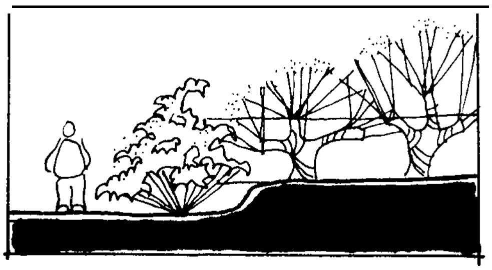
1) Architectural uses. Whether singular or in groups, plants can be used to articulate space, screen views, and define elements in the landscape.



2) Engineering uses. Engineers address problems of glare, traffic and sound control, the conditioning of air, filtration, and soil erosion. Through careful choice and siting, plants can control glare, direct traffic, absorb sound, filter the air of gases and particles, and aid in filtering suspended sediments from water. Through transpiration, cover, and spreading root system, plants can aid soil stabilization and denaturing.

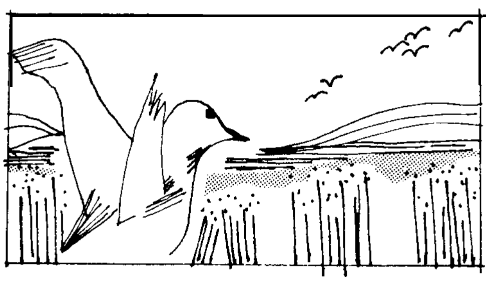


3) Climate control. The use of plants in controlling climate is well known. They aid in filtering the hot sun, thus lowering intolerable temperatures. Federal projects have sponsored the planting of tree belts to control and direct winds.



4) Aesthetic uses.

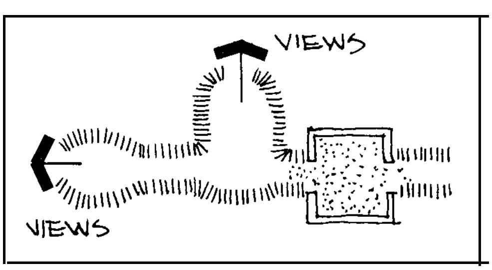
Plants as unique elements in themselves serve as focal points in a landscape composition because of the structure of branching systems, the texture of foliage, or the fragrance of flowers. Plants can unite unrelated objects in a landscape and screen those elements displeasing to view.



5) Conservation. Plants serve an important role in conservation, attracting various forms of wildlife, providing the necessary cover and organic elements necessary to retain and build soil, and above all providing food for life.

e. Approaches, circulation, and observer viewpoints

In landscape architectural practice, careful consideration is given to the perception of form, outline, texture, and placement along the sequences of space in any form of circulation. Enclosures are analyzed and valued and vistas are developed to their full potential to add purposeful interest and excitement. Circulation should be analyzed from the points of approach, sequence, and departure, each of which will have distinct visual implications.



2. Technical Considerations

a. Soil

The correct assessment and analysis of soils is an essential requirement of landscape architecture. Soil is the medium which nourishes and sustains vegetation. It supports the root systems of plants, which in turn support the visible components of the plants. It absorbs and holds the water and mineral nutrients that are necessary to the plant. Its pH value, the degree of acidity or alkalinity, helps determine the type of vegetative growth. Its salt content, which at times can be altered, has a direct bearing on the quality and type of plant growth. Salts, including alkaline compounds, tend to concentrate in the root zone or at the soil surface.

Soil is categorized according to its mechanical and organic composition. For instance, clay is a fine grained, cohesive material which can be impervious to water movement and is unusable under certain stresses and forces. The characteristics and potentials of the different kinds of soil must be known before earth forms can be designed, trees can be planted, structures can be built, and knowledge of plant succession can be obtained.

b. Water

The interaction of water with the land has a great bearing on land configuration and vegetation. Surface water from precipitation is one factor that forms the land by eroding soil away from hills and depositing it in valleys and other low points. Surface water that is not adequately drained from a site can adversely affect vegetative growth and development. Surface ponding stops air penetration in the soil and prevents aerobic activity. Evaporation of surface water takes heat from the soil; transpiration can decrease ambient temperatures.

Ground water is also critical to the growth of vegetation. The water table (the upper surface of the saturated zone of free, unconfined ground water) can limit beneficial root growth if too high. The water table is dynamic and can change dramatically in response to inundations or droughts.

C. Natural constraints

The environment is subjected to a variety of natural constraints that constantly maintain or threaten the delicate balance between vegetation and the surrounding ecosystem. These factors include winds, particularly storm winds such as hurricanes and tornadoes; salt spray and salt in the ground water; floods and the erosive effects of heavy water runoff; and freezing and thawing cycles and other effects of extreme temperatures. These factors are normally considered in the design process such that the final development plans will reflect an understanding of the nature and extent of the constraining factors.

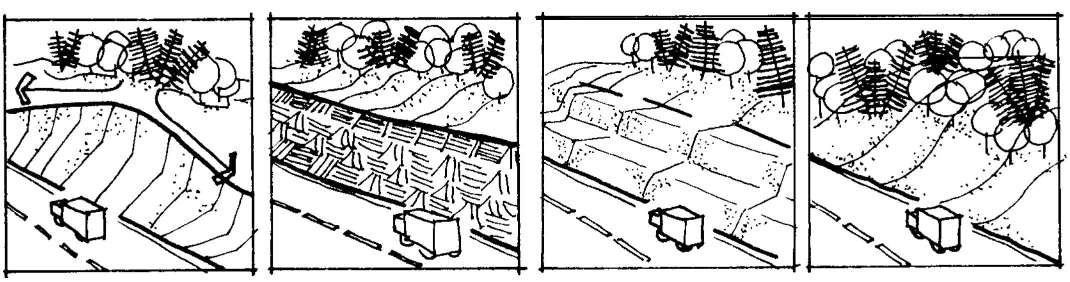
D. OVERVIEW OF SELECTED ANALOGOUS FACILITIES

Certain civil engineering facilities and projects are analogous to CDMD facilities in terms of both the problems that arise during construction and operation and the solutions to these problems that have been developed through past research in related fields. A review of the following facilities has yielded solution principles which are applicable to landscape development of CDMD's: highways, strip mines, sanitary landfills, Dutch polders, and artificial islands. The conclusion of this section summarizes the significant principles; specific applications of these principles to CDMD development are found in the recommendations of this report (Part III).

1. **Highways**

Extensive research in the field of highway development has been conducted in the past to solve the problems of structural and surface instability of steep highway fill areas and of plant establishment and maintenance on highway embankments.

Particularly on fill slopes, slumping of newly-placed fill and slippage over time may cause problems. Although avoidance of these problems is basically an engineering concern, certain common principles and guidelines should be recognized. Flattening the slope of the fill material will obviously reduce some of the physical pressures that cause structural instability; in general, granular soil can support steeper slopes than can clay materials, which must be sloped at 3H on IV or less (Department of Public Works, Canada, 1971). If it is unfeasible to thus widen the fill area, terracing or benching the slope can help to prevent slippage.



Surface drainage | *Impervious material* | *Terracing* | *Mulching and planting*

A steep slope is inherently subject to surface erosion, particularly that resulting from precipitation and runoff. Erodibility of a slope is dependent on the amount of precipitation, runoff patterns, soil characteristics, and slope length nnd angle, and can be calculated using standard formulae developed in soil engineering research. If the slope cannot be designed at a sufficiently shallow grade, a number of other measures may be taken to prevent erosion. Drainage systems that channel water away from the slope face can curtail sheet and gully erosion, as well as possibly prevent seepage behind the slope and resultant slippage.

Another technique involves covering the surface with an impervious material such as brick, stone, concrete, or bituminous pavement.

Vegetation prevents slope erosion as well as providing a visual amenity. Considerable research has been conducted on plant species and planting methods that are applicable in terms of the high erosion potential, difficulty of access, large surface areas, and limited maintenance programs on highway embankments (Zak et al., 1972).

Grasses and herbaceous legumes such as crown vetch, which are good soil stabilizers, can be planted by hydroseeding. In this process, a slurry of water, seed, and fertilizer are sprayed onto the slope; a filler of finely ground cellulose fibers or a mineral filler such as gypsum, perlite, or vermiculite may be added to serve as a mulch. On slightly steeper slopes, a filler of oil, bitumin, or latex emulsion either alone or sprayed simultaneously with straw mulch will adhere to the soil to a greater degree. However, on slopes greater than 2H on IV, a netting of kraft paper yarns or jute stapled to the slope may be necessary in order to prevent the seed and filler from washing away (Hudson, 1971).

Woody plants can be planted either by the broadcast or the spot-seeding methods, as well as by traditional planting techniques. In the broadcast method, seeds are sprayed on first, then hydro mulched with two inches of wood chip mulch; this is acceptable when the slope is 3H on IV. In the spot seeding method, seeds are planted in spots cut through the mulch; this is recommended when the slope is greater than 3H on IV.

The selection of plant species should be made only after site conditions have been evaluated, including soil texture and structure, drainage patterns, and slope orientation and steepness. Obviously, the species must be adaptable to the site conditions, as well as fulfilling any functional requirements in terms of growth rate, root structures, visual attractiveness, or screening ability.

Maintenance mowing programs may determine permissible slopes: a slope of 3½H on IV is normally considered a maximum for safe and effective use of mowing equipment. Standards have also been developed for slope combinations and curve radii which enable the economical operation of typical mowing equipment (Iurka and Tetelman, 1960).

2. Strip Mining and Sanitary Landfill

The aspects of strip mining and sanitary landfill operations which are analogous to CDMD facilities include the slopes and landforms of deposited or regraded spoil, the reclamation of disturbed, barren, or nuisance-generating spoil, and the capabilities of the spoil to support vegetation.

The reclamation of strip mined lands typically involves site regrading, using the stockpiled spoil or overburden which was removed from subsurface mineral deposits. Regrading plans should reflect an analysis of the effects of the plan on drainage patterns, particularly those that carry runoff from derelict mines onto adjacent lands, the water table, and the engineering requirements of slope and angle. A slope of 40H on IV or 50H on IV, depending on the material, is best for draininage of the regraded site; where slope embankments are necessary, a slope of 5H on IV or 6H on IV is appropriate (Downing, 1971). A basic decision to be made is whether the site should be graded in natural or geometric forms. This decision has aesthetic as well as cost implications: because the construction of undulating landforms requires the use of only one earth scraper, it is usually a less expensive operation (Downing, 1971).

Earth covers high in clay or with other impermeable materials are considered advisable over derelict strip mines in order to minimize leaching of acids and other toxic materials and to enable vegetation establishment (Hutnick and Davis, 1973). They are also necessary for sanitary landfills in order "to prevent insect and rodent infestation, blowing paper, fires,...and the release of gas and odor" (Sorg and Hickman, 1968), as well as to enable vegetative growth. Requirements for earth fill cover over strip mined sites have been established in five of the Appalachian states; Maryland requires a three-foot cover. For sanitary landfills, Massachusetts requires two feet of cover (Commonwealth of Massachusetts, 1971).

In cases where trees are to be planted, three feet of topsoil cover has been recommended (Sorg and Hickman, 1968; Commonwealth of Massachusetts, 1971).

In many cases where laws do not require it and when economic considerations preclude it, earth fill is not provided. Natural revegetation can and does take place on less than ideal sites. However, the success of colonization is dependent upon having a soil structure and texture to which native colonizing species can adapt, as well as an adequate seed source for such species.

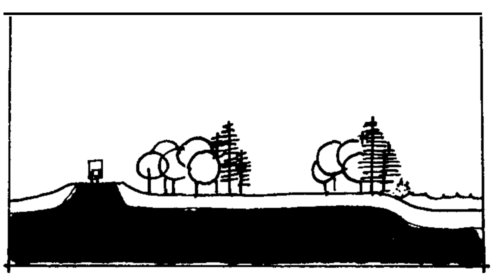
The growth of colonizing species and of trees planted in a topsoil cover is moderated by such critical factors as the pH, the composition of the earth, and the amount of water that is retained in the soil. pH values are generally high on newly mined soil, but are reduced through time as the plant cover develops through the pioneer stage. A test site in Illinois indicated that soil condition with respect to nutrient levels was markedly improved under a growth of black locust trees (Ashby, 1964).

Experiments with various planting designs and techniques have been conducted on derelict land sites in England. A number of species, including perennial rye grasses, red fescues, and other grasses, as well as willows, dogwoods, mountain ash, hawthorns, and alders have been found to perform successfully for different uses on the project sites (Vyle, 1971).

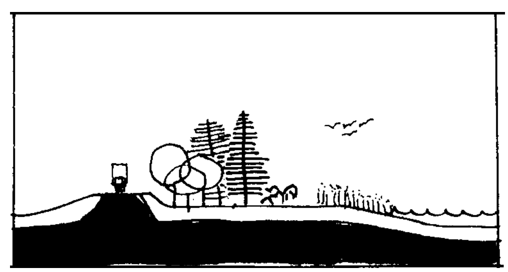
3. Dutch Polders

A polder is constructed by building an enclosed dike around land submerged in shallow water, pumping the water out, and keeping the land permanently exposed to the air. After desalination, the land can be occupied for uses such as agriculture, parks and recreation, and residential communities.

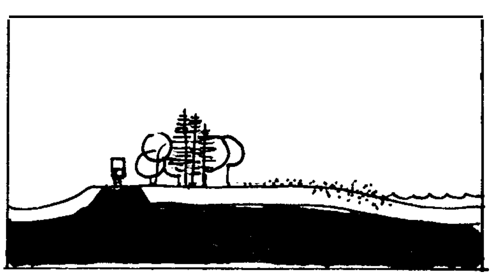
The construction of these facilities requires the utmost concern for prevention of dike failure. However, the creative modification and enhancement of the dikes as undertaken by the Dutch is of more interest to the development of landscape concepts for CDMD facilities. The Dutch have tried to adapt the polder dikes to serve a variety of uses, as exemplified in the Eastern Flevoland polder now under construction in central Holland (Van Eesteren et al., 1963). The top of the dike is used for a roadway. The side of the dike facing the water has been modified by adding additional soil; this has created additional usable land and a more natural shoreline. The distance between the roadway and the water, from twenty-five to five hundred feet in width, is used successively as a wooded parkway, a sandy beach, a shallow-water marsh for a wildlife sanctuary, and a landscaped buffer strip. The flat slope of the dike at the water's edge facilitates the cultivation of marsh species which serve to control shoreline erosion and to visually naturalize the dike.



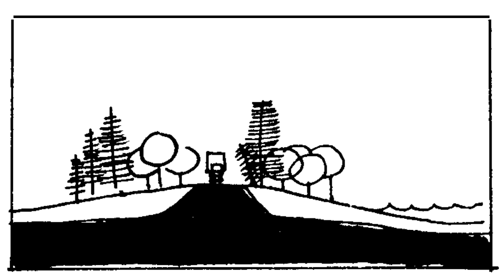
Wooded parkway



wildlife sanctuary



Sandy beach



Landscaped buffer

4. <u>Artificial Islands</u>

The creation of artificial islands has been recommended and used in several cases where space is no longer conveniently available on land. These islands can accommodate what McAleer (1974) describes as "development and nuisance uses", uses which are removed to an isolated location such as an island or artificial platform because of their potential for environmental harm or their objectionable nature. They are also suited to "conservation and attractive uses", such as wildlife sanctuaries and public or private recreation, which are less intense and can take advantage of the relative isolation.

An artificial island may be constructed in a number of forms and by several techniques. The most conventional is a diked and filled area using natural earth and stone materials in shallow water, similar to several CDMD facilities that have been constructed by the Corps of Engineers. Islands can also be formed by caisson or cellular type dikes with earth fill, pile-supported platforms, and floating platforms.

Together with the potential benefits of such structures, a number of problems may be encountered. These include possible pollution from fill leachates and potential interference with the littoral and natural beach-replenishment functions of current. Care should be taken to select sites in shoals with little potential for biotic life.

In the design of artificial islands, several principles may be employed for ensuring high compatibility with adjacent or nearby shore areas. Wherever technical, operational, and economic constraints permit, artificial islands should be given natural forms in terms of both perimeter and elevational contours. Where recreational use is planned, the desirability of such design planning should be evident. Almost all artificial islands formed for park and recreational use are naturalistic in character. In addition, indented perimeters may provide anchorages for recreational boating. Perimeter dikes or island edges which are broader than technical requirements dictate may also be managed for multiple-use recreational opportunities (Roy Mann Associates, 1973). Where utilitarian facilities are involved, the rationale may be less apparent, but no less desirable if visual incompatibility with adjacent scenic, recreational, or residential areas may be interpreted as adversely affecting the environment. Thus, offshore facilities are at times provided with naturalized perimeters. Superstructures are also provided appropriate treatment; for example, the 180-foot rigs at the THUMS oil drilling development at Long Beach, California, were baffled to resemble residential towers.

When wave erosion is a particular problem on an artificial island and when sand is available in sufficient quantities, it is often desirable to create a long, shallow-sloped beach. By building a retaining wall beneath the surface of the water, using rocks, sheet piling, or caissons, the sand on the beach can be retained at a shallow slope and may better withstand loss to storm wave action and littoral drift.

E. SUMMARY OF APPLICABLE PRINCIPLES

1. Creative Uses of Facilities which are Similar to CDMD Facilities

From the preceeding review of landscape architectural principles and the examination of selected analogous facilities, it is evident that an attempt is being made to provide creative new uses for projects that were originally intended to serve more utilitarian purposes. The most obvious examples are artificial islands, with their wide range of use possibilities. Also, through recent modification and enhancement measures, greater recreational and other use is being made of reclaimed areas. Creative reuse of surface-mined sites can be accomplished by developing recreation grounds, wildlife sanctuaries, and hunting and fishing sites. Planting on highway embankments can be used not only to ameliorate the view from the road, but also to screen the view to the highway from surrounding community areas.

2. Slope Stabilization

The stability of the containment structure of a CDMD is of prime concern to those involved in its construction, operation, maintenance and long-term use. From the research conducted, it can be concluded that two major principles apply to the design and construction of retainment dikes. The first is that for given foundation conditions, the shallower the slope, the stronger the dike. This principle applies to both surfaces of a slope, that is, a land-side slope that is exposed to the eroding effects of rain and wind and also to a water-side slope that is exposed to the eroding effects of waves in addition to rain and wind. In the first case, if highway embankments are designed to have shallower slopes, less constructional stabilization and maintenance is required and planting is facilitated. In the case of water-facing slopes, it has been demonstrated that artificial islands designed with perched beaches or Dutch polders designed with gently sloping dike edges effectively reduce dike erosion.

The second significant principle of slope stabilization is that surface erosion can be limited by reducing and controlling the force of water runoff. This can be achieved by a variety of techniques, including terracing, covering the surface with inorganic materials such as riprap, covering the surface with mulch, and using plant materials for slope stabilization.

3. Earth Forming and Preparation

Earth forming and soil preparation are important for a number of reasons. They have practical requisites for providing good drainage and erosion control and for providing a suitable condition for vegetation. They also have applicability in the aesthetic enhancement of sites such as CDMD facilities.

Regrading is the first step that must be taken to restore a strip-mined area. This is primarily for functional reasons, since the proper drainage of those areas where toxic minerals may be present is critical. Regrading has obvious visual justifications also, since the scars of high walls and spoil heaps are obvious intrusions in the natural landscape.

Earth forming can be used imaginatively to create more acceptable habitats for wildlife or more useful and human-scaled spaces for people. Grading of man-made projects should be used to blend the newly structured earth with the surrounding land forms.

Soil preparation is obviously an important requirement for the reclamation of derelict land or recycling of waste disposal sites. At the completion of a sanitary landfill operation, a minimum of two feet of topsoil should be placed to sustain a grassy ground cover. Three feet of topsoil is necessary to support tree growth. Similarly, an earth fill is recommended for covering mining tailings; three feet of earth fill is recommended as a minimum.

There are various ways of enriching the soil on top of recycled materials. To a certain extent, plant materials themselves enrich the soil and make it more productive to dominant species. Also, fertilizer is generally necessary to prepare the soil for planting or to sustain growth. However, nutrient runoff must be carefully controlled.

4. Planting: Species Selection and Planting Techniques

Plant material can enhance the image of large land-forming projects and facilitate erosion control. From the various examples discussed, it is possible to draw several conclusions that are pertinent to the landscape development of CDMD sites.

A highway or steep-sloped embankment has unique characteristics that determine what species of vegetation should be planted. Because of access difficulties and the need for maintenance, a type of tree or ground cover must be selected for which appropriate planting equipment and manpower is available. For instance, hydroseeding and mechanical or artificial mulching methods may have to be used, and therefore only grasses or trees that can be broadcast-seeded can be selected. Other considerations in selecting plant species for sloping sites are to choose plants whose roots have sufficient soil stabilization properties and will reproduce and cover an exposed slope as rapidly as possible.

A principle guiding species selection for revegetating problem areas is that the properties of the existing soil or dredged material will dictate what will grow. Only if a suitable topsoil cover is provided or if the existing dredged material is effectively reconditioned can the designer have increased freedom in selecting species for planted or seeded revegetation.

Thus, it is evident that many landscape principles and concepts exist that are applicable to the design, construction, and maintenance of CDMD facilities. Application of selected principles is further discussed in Part III of this report.

PART III: PLANNING AND LANDSCAPE RECOMMENDATIONS AND ALTERNATIVES FOR CDMD SITE DEVELOPMENT

A. INTRODUCTION

The illustrated recommendations presented in Section B, "Recommendations and Guidelines," constitute the major design concepts resulting from the study effort on which this handbook is based. Design recommendations regarding earth preparation and planting may be found in Section C, "Implementation."

Although many of the concepts presented in the following sections have been tried, tested, and constructively used in other problem-land planning and design applications, most of the concepts are new to the field of dredged material disposal. Because of this, adequate testing of the recommendations of this report should be planned, monitored, and reported on a District-by-District basis in order to determine their practicability and effectiveness in landscape improvement.

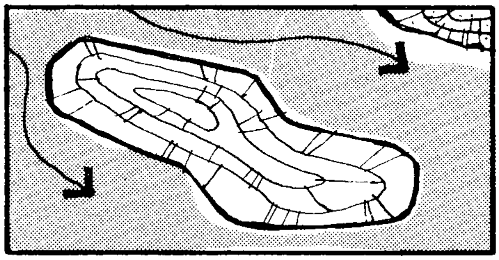
Their untried status notwithstanding, the concepts recommended in this report have been carefully reviewed as to adequacy and practicality in terms of the constraints and variables of CDMD facility engineering, operations, and maintenance technology. They are achievable, in the judgment of the authors of this report, and should assist the Districts in the pursuit of defined Corps of Engineers environmental and aesthetic resource policies and directives.

B. RECOMMENDATIONS AND GUIDELINES

1. Natural Forms

a. Recommendation

Employ simple naturalized perimeter to enhance visual blending or similarity with islands and shorelines.



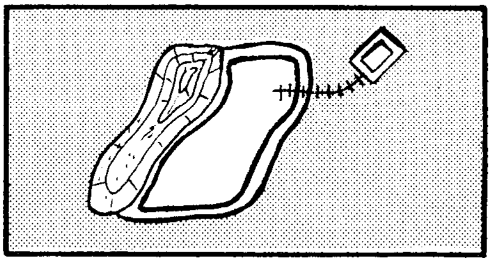
b. Guidelines and specifications

- Use rhythmic curves that are easily noticed by observers at water or shore level (more important than actual design in plan view).
- Avoid unrhythmic, ragged, and straight edges (unless straight edges are intended for a specific reuse application).
- Employ buoys, markers, or other conventional means for ensuring accurate laying out of perimeters by disposal operators.
- Use shape and orientation of island to enhance harmony with nearby land or island forms and to minimize interference with littoral drift, currents, salinity regime, and other factors.

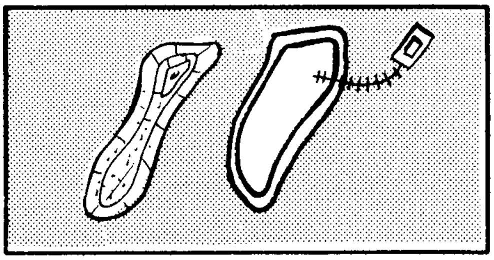
2. Proximity to Natural Islands

a. Recommendation

Where conditions allow, construct disposal facility at sufficient distance from natural island to avoid damaging aesthetic, wildlife, or recreational qualities.



Improper siting



Proper siting

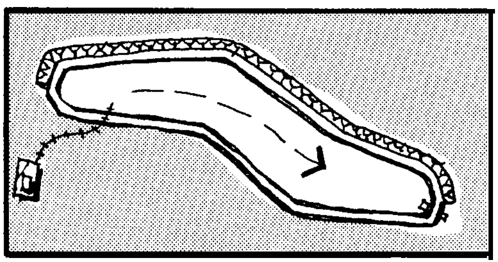
b. Guidelines and Specifications

- Carefully consider all environmental planning factors.
- Plan compatible use for sector of facility closest to island.

3. Linear Natural Forms

a. Recommendation

Use lee of existing or new breakwater for protected disposal material retention structure.



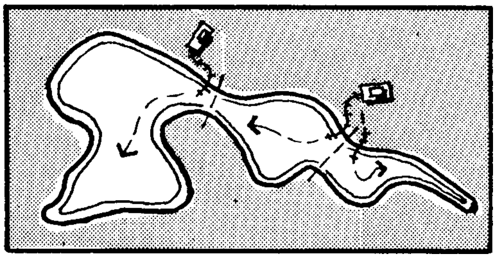
b. Guidelines and Specifications

- Construct breakwater and dike(s) as per standard design specifications but incorporate curving perimeters consistent with resistance to wave forces and related factors.
- Design breakwater lee to serve as protection for outer dike in lieu of riprap or revetments.
- When possible, place sluice at end of island where harbor currents are predominantly away from sensitive estuarine areas. Additional measures such as traps should be employed to control escape of suspended materials into sensitive areas, particularly where breakwaters (and islands) are short in length.

4. Complex Natural Forms

a. Recommendation

Develop island with complex, naturalistic form for specified reuse purpose.



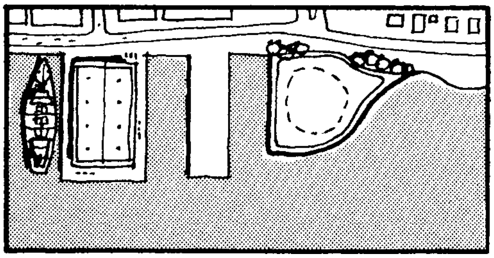
b. Guidelines and Specifications

- Prepare to-scale layout drawing for perimeter construction. Require retention structure contractor to exercise care in following markers.
- Employ appropriate earth contouring, mounding, planting, and seeding to achieve a finished island consistent with the reuse purposes of the project.

5. <u>Modified Natural Form</u>

a. Recommendation

Use modified natural forms to harmonize existing bulkheads in mixed-use waterfront areas.



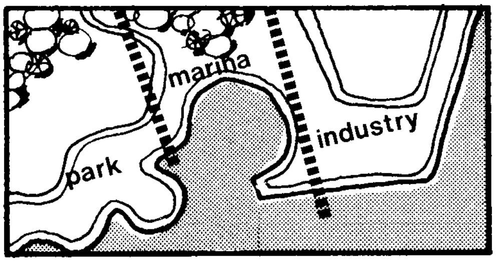
b. Guidelines and Specifications

- Employ curved edges on side(s) facing public open space, recreational facilities, or residential areas.
- Raise elevation of contained dredged material to create opportunity for future waterfront viewing point.

6. Multiple Modified Forms

a. Recommendations

Plan perimeter configuration and segment area sizes to meet intended reuse plans for multiple activities.



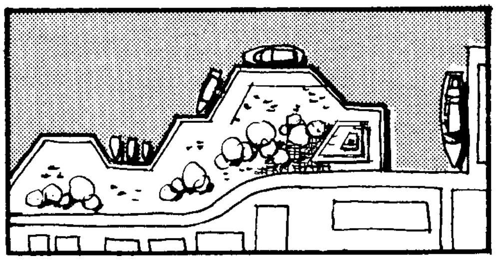
b. Guidelines and Specifications

- Develop reuse master plan upon request of and in conjunction with local sponsor and related jurisdictions.
- Lay out basic perimeters of individual use segments in accordance with needs of each use (see sketch for examples).
- Add final form to perimeters of complex edges after disposal operation is completed within the more simple perimeters.

7. Modified Angular Forms

a. Recommendations

Employ perimeter form carefully designed to complement rectilinear edges of mixed or urban/industrial waterfront without copying its rigidity.



b. Guidelines and Specifications

- Design perimeter geometry in advance.
- Where feasible and consistent with local sponsors' plan or agreement, wood bulkheading or finished masonry walls are preferable to either steel sheet-piling or riprap.

8. <u>Bulkheading Variants</u>

a. Recommendation

Where the retention structure is planned along a bulkhead line, set bulkheads or revetments back slightly at intervals to enhance rhythm.

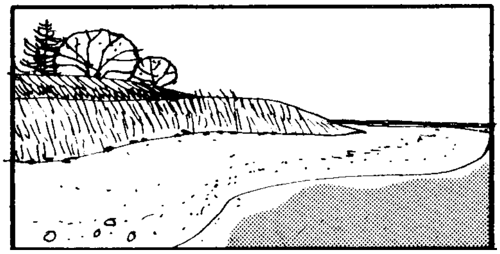
b. Guidelines and Specifications

- Employ 45^{o} angles or 60^{o} angles at corners.
- Plant trees and shrubs in salients.

9. <u>Beach Variants</u>

a. Recommendations

Where artificial nourishment or natural establishment of beaches is feasible and planned, use special measures to ensure perimeter visual quality.



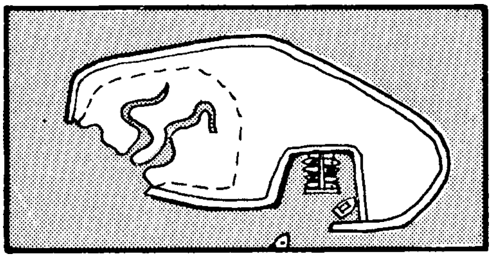
b. Guidelines and Specifications

- Employ cast mattresses or other protection that will not protrude (as would riprap) through the sand overlay.
- Use as shallow a slope as feasible for the outer face of the retention structure, preferably not steeper than 4H on 1V, to optimize vegetative take and minimize r-ill erosion.
- Seed and/or sprig entire face of retention structure along planned beach area. Plant shrubs and trees on crest (see Section C3, Plant Establishment for further guidance).

10. Lee Variants

a. Recommendation

Employ indented configuration for lee perimeter to accommodate selected reuse purposes.



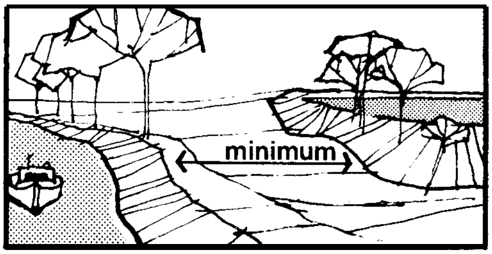
b. Guidelines and Specifications

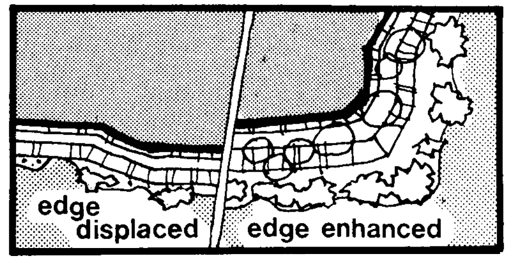
- Provide appropriate indentations, disposal material, and plantings for marsh establishment and wildfowl management.
- Provide deep indentation for holding basin, to be reused as boating facility.

11. Riversides

a. Recommendation

Design riverside or channel-side disposal facilities for best possible landscape compatibility.





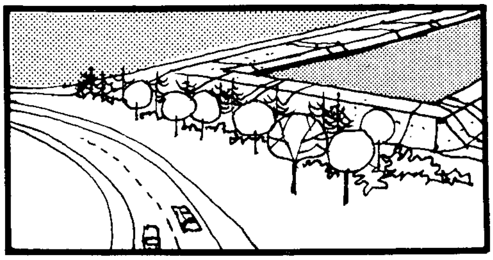
b. Guidelines and Specifications

- Establish minimum setback (see 16, Setback). Where a road is required between river and facility, set toe of slope back from road an additional distance.
- Vary retention structure perimeter along lines sympathetic with river edge.
- Plant trees and shrubs on face and crest of facility, particularly those sides which face the river or public and occupied areas.
- Concentrate disposal into minimum surface area feasible (with appropriate mounding design) in order to conserve floodplains to the highest degree possible.

12. Land-Facing Edges

a. Recommendations

Design edges that are compatible with existing and potential adjacent landscape and land uses.



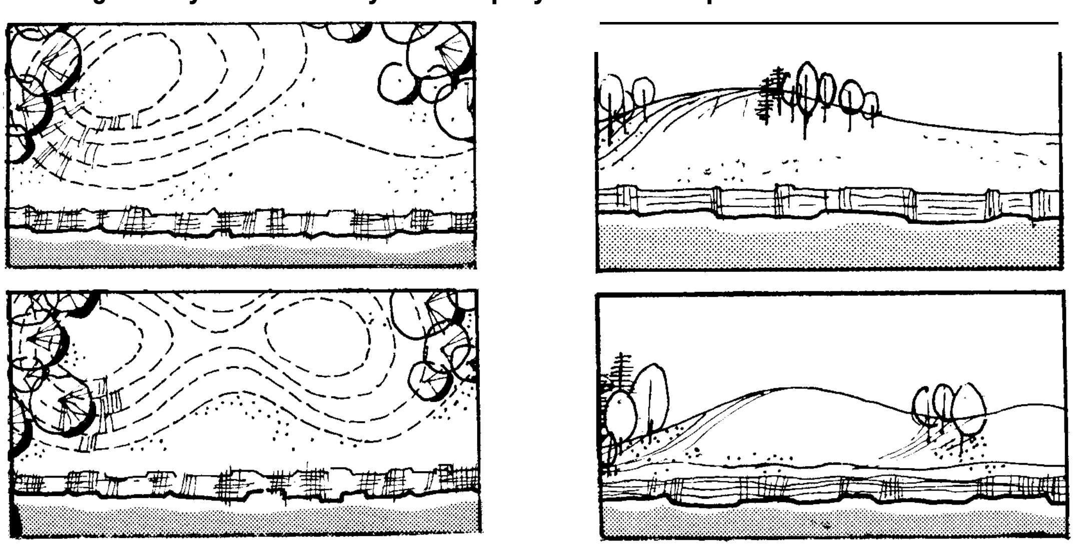
b. Guidelines and Specifications

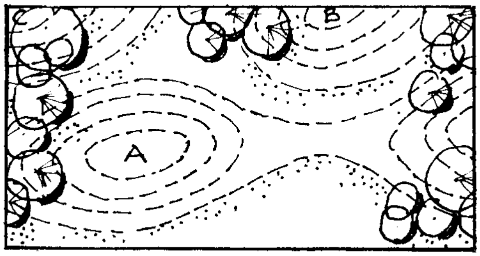
- Set perimeter dikes sufficiently back from property lines, public roads, other public viewing points, and contrasting land uses.
- Employ foreground berms, mounds, and plantings to screen views of disposal facility.
- Avoid straight dike edges parallel to roads or within exposed view of adjacent contrasting land uses.
- Where foreground areas within property lines are abandoned farmlands or areas with unsightly elements, landscape designs should be provided for their amelioration. Normal or attractive foregrounds should be enhanced or protected. In either case, additional plantings of indigenous species, in suitable numbers and plant groupings, should be provided.

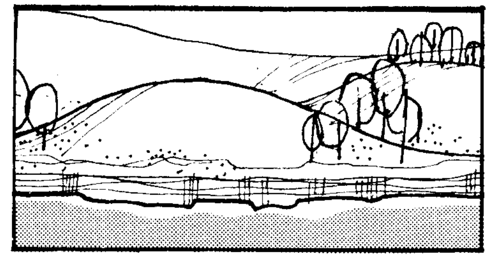
13. Perimeter Mounding

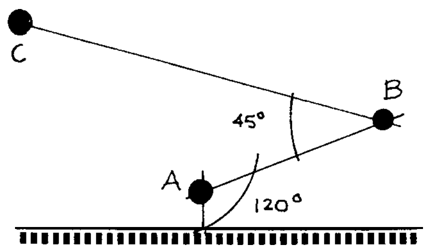
a. Recommendation

Mounds should be developed on disposal facility perimeters to enhance their form qualities and to heighten the visibility of selected tree and shrub groupings. Three basic mound patterns are recognized although many others may be employed with equal effect.





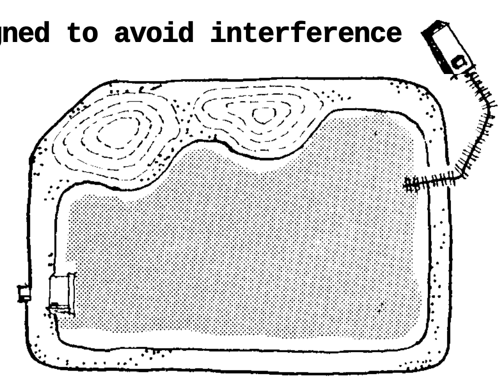




One attractive variation is obtained by placing C twice as far from B as B is from A. Height is pleasingly varied by bringing the elevations of the three mounds to 25, 30, *and* 35 *feet respectively.*

b. Guidelines and Specifications

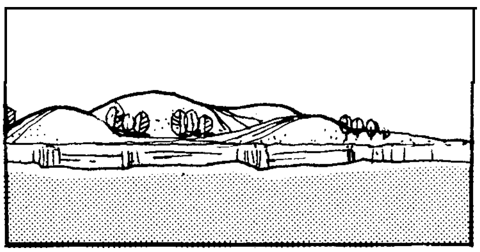
- **Uewatered disposal material should be mounded on top of perimeter dikes. As each incremental dike is constructed, a new mound should be raised in proximity to the earlier mounds. Tree and shrub planting, as well as grass seeding, should be carried out as early as feasible following the completion of each dike and mound stage.**
- **The toes and crests of the mound slopes should be well rounded. Slopes should be 4H on 1V or shallower where possible to minimize erosion and enhance planting establishment and ease of maintenance. (Other erosion constraints will also apply as indicated in Table 3.)**
- **Mound dimensions should relate to dike width, but should be permitted to encroach on disposal area where width is sufficient. The resulting salient should be designed to avoid interference with effluent movement.**

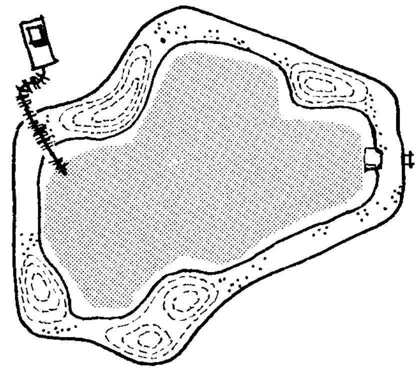


14. Mound Silhouette Control

a. Recommendation

Interval spacing and heights of mounds, particularly those on perimeter dikes, should be varied to increase visual interest and avoid monotony.





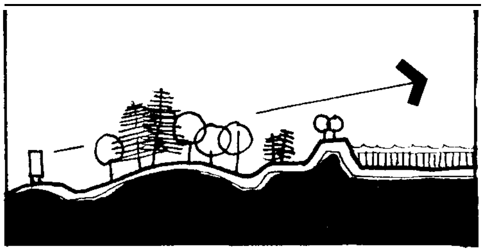
b. Guidelines and Specifications

- Mound placement should be neither too sparse nor monotonously close-spaced, but should occur at a freqency that breaks up the rigid elevation view of the facility.
- Spacing and heights should be varied and mounds should be grouped where feasible.
- An effective minimum construction plan should include a mound or mound group near the intersections of major sides of the perimeter structure.

15. Foreground Berms and Mounds

a. Recommendations

Placement of berms and mounds in the foreground of an on-land disposal facility which is exposed to major public view or to adjacent contrasting land uses will aid in screening and enhancing facility appearance; this may be particularly useful in initial stages of project or where retention structures cannot be widened to support in-structure mounding and planting.



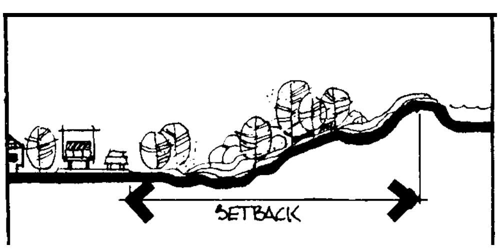
b. Guidelines and Specifications

- The mounds or berms should be varied in height, form, and distance from the viewing area to avoid the appearance of a monotonous wall or concealing structure.
- Types of vegetation planted should be consistent with the plant species already established on adjacent lands.

16. Setback

a. Recommendation

Retention structure should be set back sufficiently to permit screening of CDMD facility.



b. Guidelines and Specifications

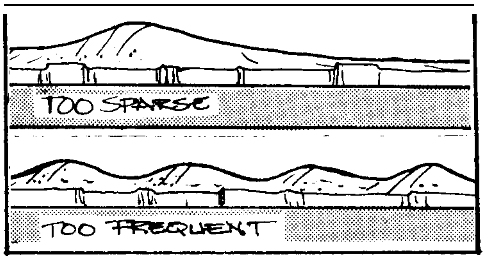
- Setback from public roads, public viewing points, and contrasting land uses (residential, most institutional, and others) should be sufficient to permit accommodation of foreground berms and mounds (see preceding recommendation). Screen vegetation and other elements for enhancement.
- Normal setbacks from property lines required for CDMD facilities may be adequate; additional setback should be provided where view

and land-use conditions warrant.

17. Interior Mounding

a. Recommendation

Grade dewatered disposal material into mound/hill or varied topography in the facility interior.

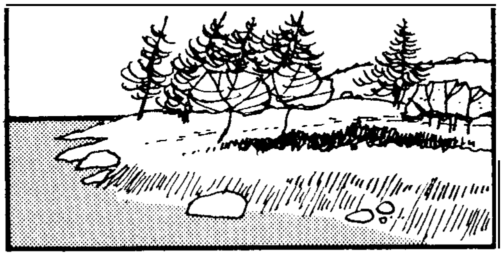


b. Guidelines and Specifications

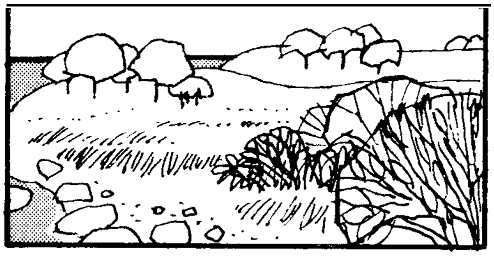
- Relate interior mounds/hills with final graded retention structure for integrated landscape.
- Use final grading plan to determine desirable locations for borrow areas and increase the setting out of coarser materials in such locations (see Design Details, Section 19, for further guidance).

18. Planting Recommendations

Select species that are compatible in visual groupings and pattern them harmoniously with topography.



Select species that are part of the same native plant community. Select species that are easily self-propagating and fast growing.

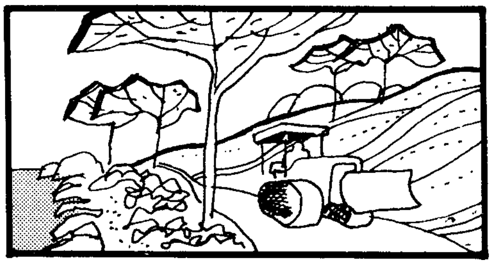


Use masses of trees and shrubs with adequate spacing, rather than specimen, row, or patchy plantings.

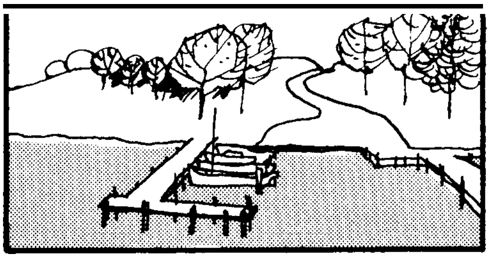
Select species that are well adapted to identified moisture, soil, winds, spray, and other conditions; plant lists are given in Tables 7-9.

Densely plant evergreen trees or shrubs where screening would be especially beneficial.

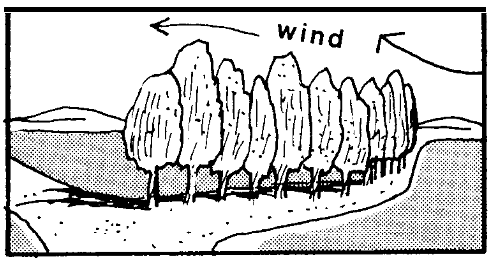
Plant dike faces and crests to enhance blending of vegetation forms with topography.



Plan plantings and provide sufficient dike crown width to accommodate both plantings and operation roads.

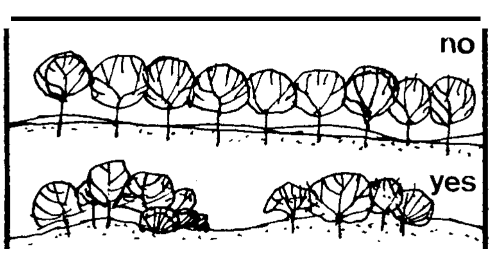


Use plantings for focusing access points and other elements of interest in intended reuse areas.

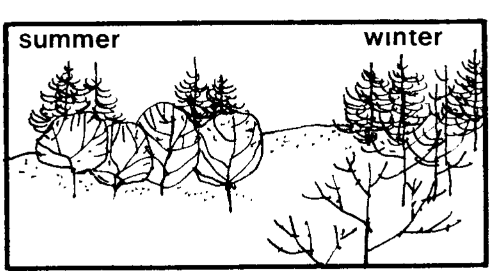


Use wind-resistant tree and shrub species for windbreaks on cross dikes to reduce wave buildup within disposal areas.

Consider permeable berms of naturally or artificially deposited shell or gravel, where ecological and accretional conditions are favorable, to aid in protection of dike and promotion of marsh and tidal pond growth.



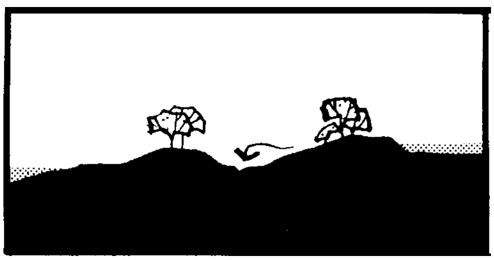
Plant in clusters so that mature crown masses can present strong visual form. Avoid single row plantings, since they reinforce rigid qualities of the dikes.



Evergreen trees should be planted on dike slopes and crown above deciduous trees and shrubs. Masses will appear more opaque. Evergreens will continue masking effect in winter in northern Districts.

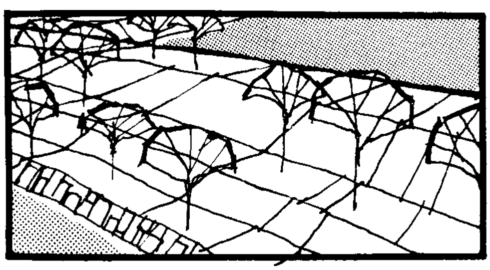
Evergreen shrubs, when planted as understory or edge plantings below deciduous trees in northern Districts, can provide strong winter features.

19. <u>Design Details</u>



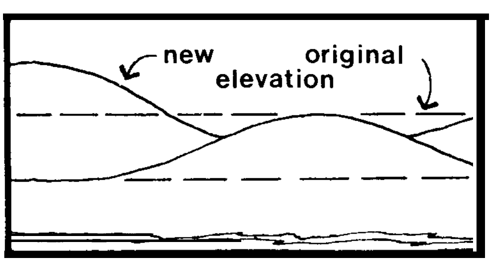
<u>Seepage ditch and berms</u>

Where seepage occurs or is likely on onshore or inland sites, provide drainage ditch and view-buffering berm on shore and public sides.



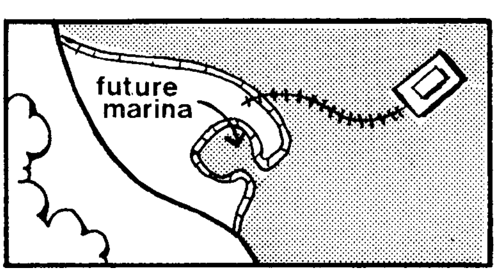
<u>Dikes as terraces</u>

As incremental dikes are constructed, trees and shrubs may be planted on the terraces, as well as on the crest of the uppermost dike.



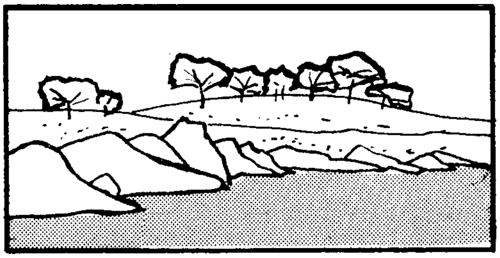
<u>Regrading of incremental dikes</u>

Regrading perimeter of completed disposal facility or completed segments. Raise and lower alternating areas by conventional cut-and-fill techniques.



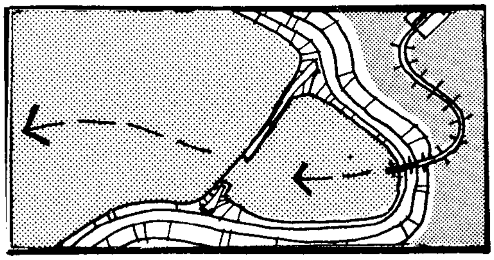
<u>Rehandling basin</u>

Incorporate rehandling basin within overall facility perimeter to decrease handling equipment exposure and to improve reuse potential of basin as future marina.



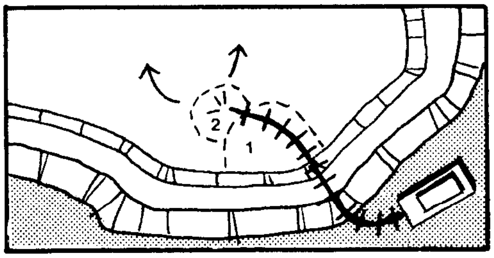
Dike edge

Use quarried or field stone in wide size range, including large boulders and slabs, and arrange them in a naturalized and varied, rather than regimented, fashion.



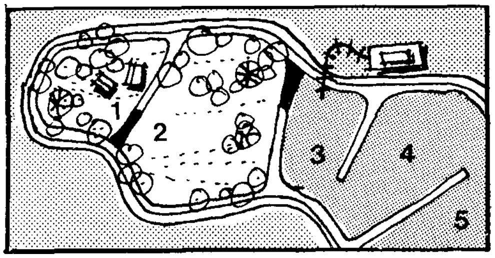
Coarse material

Where dredged material contains too high a proportion of fines (clays, silts) to ensure successful rooting of planned plantings, use of a bleeder pipe may be employed to promote settling out of coarse materials in a spur-diked containment, or in proximity to intended plantings (to minimize later hauling).



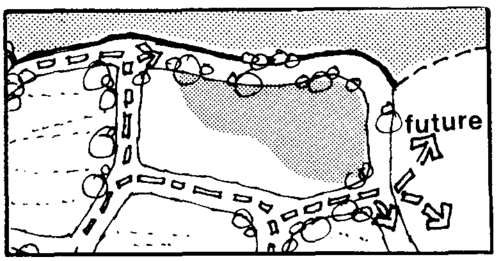
Thickened slurry

Increase slurry percentage, as feasible, to increase deposition of material around pipe outfall. Pipe dike can be extended to adjacent locus for continued filling. Loci should correspond to point where grading and mounding are to be extensive. Grading equipment and bulldozers will be used to accentuate forms built upon these initially shallow rounds.



Phasing

Plan the phasing of disposal operations to permit early reuse and landscape enhancement of the facility. Use spur dikes and cross dikes to complete segments.



Cross Dikes

In planning, consider future use potential as trail alignments in park and recreation facilities.

C. IMPLEMENTATION

1. Plant Selection Criteria

a. Introduction

The selection of suitable plant materials will be a key element in any CDMD facility landscape development program. Selection of appropriate species will be largely dependent on the location, physical design, and operational characteristics of the facility; the aesthetic and functional objectives to be achieved through plant establishment; and the site's physical constraints to plant growth and development. The potential physical contributions of higher plant species to soil/dredged material stabilization, erosion control, dust control, and modification of detrimental wind flows necessitate careful consideration of suitable species. In addition, the visual quality of CDMD facilities can be significantly improved through the introduction of masses or groupings of tree specimens or other plant materials. Desirable views can be directed and undesirable elements screened. The visual appearance of the facilities can be given variety in form and texture and geometric elements can be softened if the visual characteristics of plant foliage, branching habits, and leaf and bark colors are used attractively.

The sections that follow below, Section l-b through l-e, list and define criteria to be considered in the selection of plant materials for CDMD facilities. Those that are asterisked are further checklisted against specific plant species in the Plant List, Table 7. (Because of their length, Tables 7-9 were placed at the end of Part III.) The plant lists were compiled from selected sources, which are identified in the Plant Lists section of the Bibliography.

Table 7, Plant List for Trees and Shrubs, lists those trees and shrubs that, from a review of the relevant literature, appear to be capable of establishment on CDMD sites and for which information regarding selection criteria was readily available. Additional trees and shrubs are listed in less detail in Table 8. Selected herbaecous plant materials are listed in Table 9. Because identification of suitable herbaceous species has been adequately covered in other literature and because more immediate visual effects on a larger scale can be obtained through the use of higher plant forms, herbaceous species are not discussed in depth in this report.

The plant lists are intended to function as a basic framework for initial selection of potentially appropriate species. Where expertise in plant selection is available locally, proper guidance should be solicited in the final determination of species for specific CDMD facilities.

b. Plant community characteristics

Careful analysis of the community characteristics of neighboring and local environments in the vicinity of the CDMD facility will provide guidance in the selection of suitable plants. A community can be defined as a grouping or assemblage of organisms living in a prescribed area or habitat. The term "association" is sometimes analogously used, but generally refers to a more specific grouping of organisms such as an association of plants.

The attributes of communities will vary according to diversity of species, the relative abundance of species, the nature of the trophic structure or food chain, the types of growth forms (e.g., trees, shrubs, herbaceous species) and the dominance of certain species over others. Of these, dominance is probably the most important in terms of plant selection, because dominant species will largely determine the conditions under which associated species will grow. In typical mixed woodlands, for example, stands of dominant trees will provide the shade necessary for the growth and development of lower forms of vegetation. In addition, rapid-growing species will provide protection for slower growing species that eventually will become dominant. The faster growing species will shield humus from the sun, retarding its decay and enhancing moisure retention. Thus it is important that an understanding of the functional characteristics of plant associations in neighboring environments be understood so that those effects deemed desirable can be replicated in the establishment of plants on the CDMD facilities.

The desirability of selecting vegetation endemic to the project locale is also of key importance. Plants native to the area will signify their ability to adapt to the particular physical, hydrological, and climatic characteristics of the area or region (e.g., winter and summer temperatures, frosts, winds, sunlight intensity, fluctuations in available water, and air humidity) as well as indicate qualities such as the species' ability to self propagate locally.

Knowledge of these constraints will also aid in the selection of exotic species to be introduced to the CDMD facility. However, exotics may require higher maintenance (e.g., irrigation, nutrient additives, and pruning), because of their variant horticultural characteristics.

Care must be taken in the selection process, however, to analyze the value and potential magnitude of self propagation. In some cases, undesirable species may spread beyond control over an entire facility, preventing the establishment of more desirable species. In addition, self propagation cannot be anticipated with any accuracy as to timing within the short term or to spread to remote areas of the facility.

C. Visual parameters

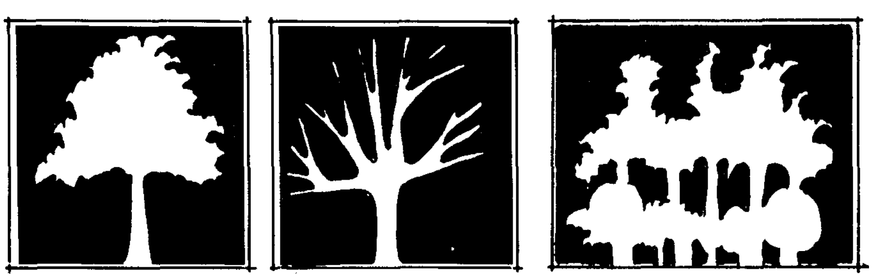
While all of the plant selection criteria are highly interdependent, certain criteria are listed below as visual parameters because they will be more significant determinants of the visual qualities associated with the establishment of various species. (Asterisk indicates checklist item in Table 7).

1) Planting size and technique*. Planting size should generally be sufficient to provide early visual effect, yet small enough to permit ease of establishment and maintenance within the economic constraints of the project. Planting trees of a large size will provide an immediate visual effect in limited quantities and at greater expense; planting trees of smaller size will provide less immediate visual effects in larger quantities at relatively lower expense. Priorities should be established early within the design phase so that the planting may be coordinated with the immediate and future needs of the site. The sizes of species to be planted will also be dependent on the availability of stock from local nurseries and other sources. Regional and seasonal variations may limit the selection process and should thus be considered early in the design phase.

2) Growth rate*. Plants will respond to various growing conditions by exhibiting different rates of growth. The genetically determined characteristic growth rate of a particular species will be modified by soil conditions, climatic factors, and other parameters. Fast-growing plants include many soft-wooded and short-lived species; most hardwood species are relatively slow growing and long-lived. Relative growth rates are indicated on the plant lists by three indices: F (Fast), M (Medium), and S (Slow).

3) Height*. Height, as indicated in the plant lists, refers to the average full height a plant species will attain under optimal growing conditions. Variations in climate, water and nutrient availability, and other factors will modify characteristic heights. Height has obvious implications in the landscape development of CDMD facilities, as the heights of plant materials will affect the silhouette of CDMD facilities and width and extent of views. Heights are given in feet in the plant lists.

4) Silhouette*. The highly geometric forms usually associated with the visual images of CDMD facilities can be softened or accentuated in silhouette by the selected addition of plant



materials. Trees and shrub clusters, either singly or in masses, can create strong visual images. In addition, silhouettes will change in character from season to season: foliage will reinforce the effect of mass plantings, while the loss of foliage in the winter will delineate branching habits or patterns and will expose or amplify views of evergreens. Silhouettes will also be strengthened by dense understory or continuous vegetation. Representative silhouettes for selected species are illustrated in the plant lists.

5) Foliage/trunk characteristics*. The visual images of tree trunks and foliage will vary with the distance from which the species are viewed and the individual characteristics of the species. Tree groupings that result in continuous visual images of masses when viewed from a distance, will be seen as a series of varied foliage textures and branching patterns when viewed from nearby. Likewise, trunk characteristics will vary in texture and color among species.

On the plant lists, the abbreviations used to describe foliage and trunk ("F/T") characteristics are: "E" - evergreen (foliage throughout the year) and "D" - deciduous (leaves lost in winter). Tonal color qualities are also noted, e.g. "light green", "silvery", and "a/c" (autumn color).

d. Physical parameters

1) Zone of hardiness*. The hardiness zones are defined on the basis of average annual minimum temperatures and should be used as general guides in the plant selection process. Variant micro-climates within a given area may permit the growth of vegetation otherwise indicated as excluded (Wyman, 1951). Figure 2, Hardiness Zones of the United States and Canada, is placed immediately before Table 7 for its use in conjunction with the plant lists.

2) Tolerance to salt spray*. Few plants identified in the plant lists are capable of growing in close proximity to salt or brackish water. However, many are capable of growing within a zone affected by minor amounts of wind-borne salt spray and are indicated accordingly.

3) Tolerance to disease and insects. The selection process, aided by an empirical knowledge on a region-by-region basis, should consider the diseases and insects particular to the area and the ways, if necessary, of controlling or eliminating them. Plants with high resistance to disease infection and insect infestation should be selected whenever possible.

4) Optimum soil condition*. Different species will develop and grow optimally in different planting mediums. These are indicated for each species on the plant list by the following abbreviations: L (loam), Sn (sand), G (gravel), Sl (silt), and Pt (peat). Although these are soil rather than dredged material types, plants for CDMD sites should be selected that can survive well with only minimal, if any, medium treatment.

5) Optimum root zone moisture*. Plants selected for CDMD sites must be adaptable to the moisture content range of the planting medium. Optimum root zone moisture is indicated on the plant lists by M (moist),1 (intermediate), and D (dry).

6) Drought tolerance*. Drought tolerance is another expression of the plant's root zone moisture requirements. Where indicated, plants tolerant of prolonged periods of drought should be used in areas where watering is difficult and expensive. Drought tolerance is indicated on the plant lists by the abbreviation "Dt" .

7) Tolerance to changes in the water table. Over the years, the water table will change as a result of changes in the land formation and the eventual drying of the dredged material. Plants tolerant to such changes should be used.

In addition, short-lived plants or mixtures of plant types can be used to provide the diversity needed for the changes expected over time.

8) **Root system.** Plants with tap roots or deep root systems should be used where earth mounding or diking of considerable height above freshwater table is planned.

e. Vegetation as a food source for wildfowl

The establishment of vegetation on CDMD sites will provide a direct food source (e.g. Zizania aquatica, wild rice) for many species of wildfowl and other forms of wildlife. Indirectly, plant species will provide habitats for insect life which in turn will be preyed upon by wildfowl and terrestrial animals. Protective cover for wildfowl can also be supplied by introducing plant species such as Rubus spp. (bramble). If the attraction of wildfowl to a CDMD site is a desired objective, care must be taken in the selection of plant materials to avoid establishing plant species that will prevent the establishment of those species of higher food value to wildfowl.

f. Shelter belts

Careful location of spur and cross dikes and the planting of shelter belts can help to control the detrimental effects of wind and minimize turbidity in the dredged material. A careful investigation of prevailing winds, particularly during seasons when disposal operations are active, will dictate the location of shelter belts.

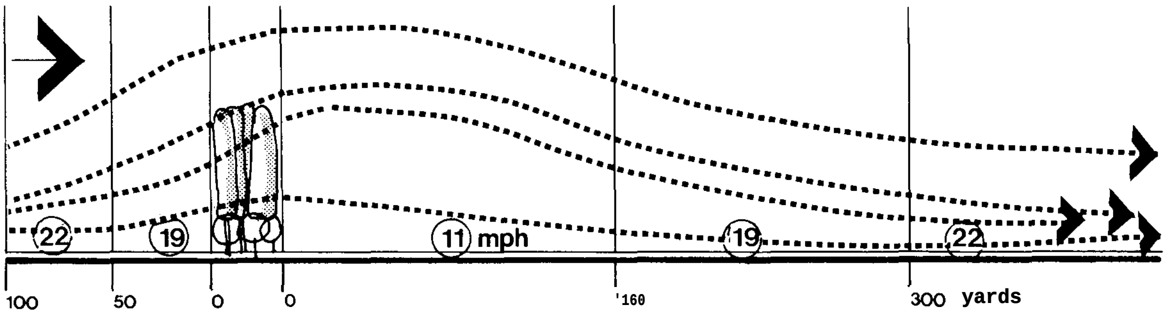
As shown in Table 10 and Figure 3, the reduction of windspeeds on the leeward sides of shelter belts can be quite significant. For example, for a 30-foot shelter belt of medium density, a wind speed of 100 mph at 100 yards to the windward side of a shelter belt perpendicular to the wind will be reduced to 36 mph at a distance of 50 yards to the leeward side. It should be noted that a parallel series of windbreaks do not proportionately reduce wind speed.

A mixture of deciduous and evergreen trees will provide the

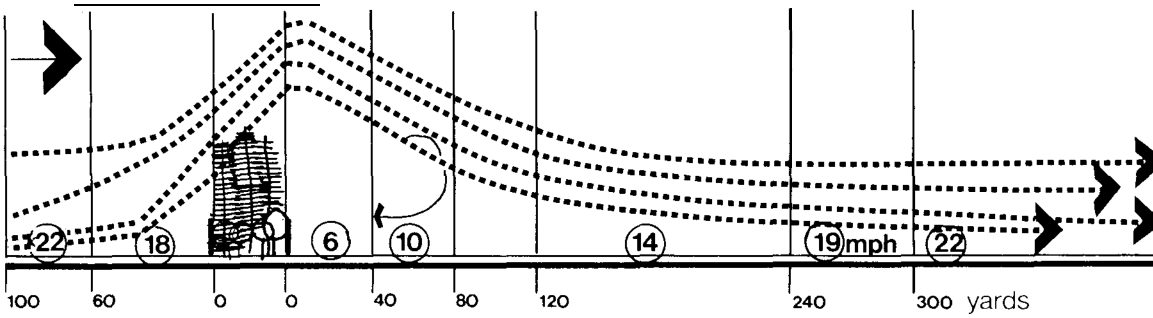
Figure: 3

Windbreak Effect

a: Moderately penetrable windbreak



b: Dense windbreak



Effects of windbreaks on the flow of wind. Figures circled denote approximate wind speeds in the various sections. Horizontal distances (in yards) refer to windbreaks 30 ft. tall (after Kuhlewind, et al., 1955).

Table: 10

Wind Speed Reduction

Wind speeds near 30-ft high shelter belts of different density.
(After Caborn, 1965).

WIND SPEED AS A PERCENTAGE OF THE UNOBSTRUCTED WIND SPEED

Density of Belt	At Distances to Windward of Belt of (yards)			Within the Belt	At Distances to Leeward of the Belt of (yards)							
	100	50	0		0	20	50	100	150	200	250	300
Very open	100	98	94	96	102	80	72	69	74	86	97	100
Open	100	96	70	75	60	40	48	75	87	95	99	100
Medium	100	96	65	62	55	37	36	60	77	89	95	100
Dense	100	96	55	--	40	27	42	70	86	94	97	100
Very Dense	100	95	55	--	15	27	58	82	91	96	99	100

most effective wind shelter over the longest distance to the leeward of the shelter belt since a continuous cover of moderate density can be achieved from the base to the tip of the windbreak. Plants chosen of various heights and foliage characteristics will provide such a composition over their life span.

Tree species that are particularly suited to use in shelter belts include: Pinus, Thuja, Chamaecyparis, Fraxinus, Alnus, Betula, Salix, and Populus (Caborn, 1965). However, care should be exercised in selecting species adaptable to the physical conditions of the site as well. In addition, some species will be more wind tolerant and thus more suitable to the windward sides of shelter belts than other species.

2. Earth Preparation

a. Introduction

A planting medium (soil or dredged material) will normally require pre-planting preparation to: 1) promote aeration, essential to root viability; 2) incorporate nutrients contained in leguminous plants and chemical and organic fertilizers into the subsurface; 3) improve the texture of the medium to facilitate root extension, which in turn will improve nutrient and water uptake capability; 4) allow the soil to absorb precipitation and runoff as well as to drain adequately to a subsurface water table; and 5) facilitate the actual implanting of plants, seeds, or other propagative materials.

It should be understood that soil and dewatered dredged material can be physically improved only to a relatively small degree, because of their fixed inherent characteristics deriving from parent geology, particle size, climatic and hydrologic influences, organic content, and general fertility. Rather than undertake extensive ameliorative methods, therefore, plants tolerant to the surveyed conditions should be selected. However, within the limits of its capabilities, a dredged material can respond to various measures identified collectively as "earth preparation." These measures, discussed below, require effort and cost and are thus to be considered specific only to the actual areas planned for planting within the overall disposal facility.

b. Key considerations

1) Dredged material types. The generalized dredged material types identified in Table 6 (e.g., mud, silt, sand, peat, mixed types, etc.) pose varying constraints to landscape development that are important in the earth-forming phase of design as well as in terms of visual concerns and pre-planting preparation. Clay, silt, and organic materials, for example, exhibit the visual effects of erosion more readily than sands or gravels. Clay may retain salts at levels prohibitive to vegetative growth, will shrink and crack over periods of drought, and may prevent the proper drainage necessary for many types of vegetation. In gravel or sand, however, most salts, including valuable nutrients, may be leached out, and a planting medium of poor fertility may result. Gravel and sand may also retain too little moisture for many plant species. Drainage amelioration techniques are discussed below.

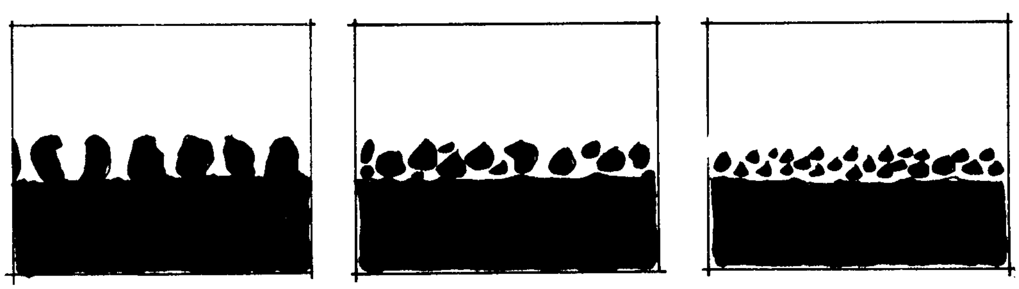
2) Cultivation. Modes of cultivation applicable to dredged material preparation include tilling or ploughing, disc harrowing, and rototilling. Equipment in each mode is available in both tractor-mounted and tractor-drawn models.

The purpose of ploughing dewatered dredged material is threefold: 1) to break up the material to improve texture and drainage; 2) to rid the surface of any vegetation that could prove competitive to the introduced planting; and 3) to incorporate the nutrients of the destroyed plant material into the subsurface.

Deep ploughing will be necessary on material with high clay content and where impervious layers (clay pans or hardpans) have formed at shallow depths. Such layers may result from intermittent disposal and drying out of high-clay dredgings. Subsoil plows that can reach depths of 2-3 feet are recommended on high-clay material. Other material types may be plowed no deeper than 14-15 inches. Deep ploughs normally work one furrow at a time, being available as single-shared or double-shared ploughs.

Smaller ploughs, available singly or in gangs up to 6 in number, should be used to break up the large clods turned over by subsoil plowing or used directly on the more easily worked, friable materials.

Discing is the next step in the cultivation process. The purpose of discing is to further break up the ploughed ground in preparation for seeding. On tougher materials such as clay, an intermediate step may be necessary in which a spring-toothed harrow is used. Discing may be necessary in two passes (crosswise) before a suitably granular seedbed is achieved. Disc harrows range in size from 3 to 25 feet in width and have the capability of penetrating up to 10 inches in depth, with an average depth of 7 to 8 inches. On sandy soils a discing depth



of only six inches may be necessary. Rototillers may also be used instead of disc harrows. Rototillers are capable of tilling widths of 2 to 3 feet and to depths of 6 inches.

3) Drainage amelioration. The dewatered material, in order to be productive to plant growth, should contain a balance of coarse and fine-grained particles to allow both drainage and retention of moisture and nutrients through adsorption, gravity flow, and capillary action as well as to provide the voids necessary for the exchange of gases essential to the habitat of soil organisms and to root activity. Movement of material when wet and its compaction by heavy machinery during CDMD operations can damage soil structure. Prior to planting and material preparation, therefore, an inspection of the site should be made to determine the extent of compaction and the need for ameliorative tilling.

Drainage may be improved by selectively depositing higher proportions of coarser materials within or through the upper horizons of the filled area. In sand, gravel, and other droughty materials, clay and silt may be added to improve the adsorptive capacity needed for moisture retention.

Soil or material may also be mounded up above the level of poor drainage to create micro-areas or pockets of free-draining land. Large massings of vegetation not tolerant to wet soils may be effectively accommodated in this manner.

Where dredged material is poor in structure and the addition of nutrients will not adversely affect water quality in the external environment, organic matter such as manures, woodchips, and straw may also be added. Compensation for soil nitrogen depletion resulting from bacterial decomposition of straw and wood chips may be required if planting is planned in the growing season following the straw or chip addition. The application of a nitrogen supplement at a rate of 50 pounds of the selected fertilizer per ton of straw or woodchips per acre of land may be effective in maintaining a desirable nitrogen level. Another supplement, sewage sludge, barring heavy toxins and pollutants, may be applied at a rate of 10-20 tons per acre. If odor should prove to be a problem, the sludge could be disced in to a depth of 6 to 7 inches. Ploughing in of lime into high-clay materials can promote the binding and aggregation of particles and result in improved pore space and rooting conditions.

4) Plant nutrients. A knowledge of the availability of nutrients within the dredged material, based on the testing of representative material samples, is a necessary prerequisite to the selection of plants tolerant of low or high nutrient or salt levels, the application of selected nutrients to dredged material of low nutrient levels, and the proper timing of planting, which should be carried out on dredged materials with high levels of nutrients or salts only after adequate leaching has taken place. Samples of the dredged material should be collected from all representative areas where planting is planned in the CDMD facility.

Nitrogen (N) is essential for chlorophyll and protein development and thus for the healthy development of all plant parts, but particularly the stems and foliage. However, overly lush top growth with poor root systems may be promoted if excessive amounts of chemical nitrogen are applied; the resulting growth condition causes high vulnerability to drought and frost, either or both of which occur frequently at CDMD sites. In order to avoid this, little or no nitrogen should be applied in the first several years of plant growth, other than during the earth preparation process when organic fertilizers or time-release chemical fertilizers may be applied. The slow release of nutrients in the latter should prevent the rank growth effect of excessive nitrogen availability.

Phosphorus (P) is an important factor in the development of root systems as well as the leafy parts of plants. Since phosphorus becomes fixed in the soil, it is essential in the discing process to mix this nutrient deep into the dredged material. This will promote the deep root system necessary for obtaining moisture in the deeper soil horizones and for drought tolerance.

Potassium (K) contributes to the general strength of the plant, disease resistance, deep rooting, and seed production. Potassium is also used in countering excessive nitrogen uptake, thus controlling or minimizing succulent and weak growth (Dept. of Public Works, Canada, 1971).

Again, it must be stressed that runoff of the nutrients into surrounding waters should be carefully controlled.

5) pH Value. pH value, or hydrogen potential, is a measure of alkalinity or acidity. The vast majority of plants are suitable for soils of neutral pH. However, certain higher plants have adapted themselves to slightly acid or alkaline soils. Such plants should be noted for CDMD facility landscape development since facility conditions of acidity or alkalinity may necessitate the selection of such species (Tandy, 1970).

The pH level has been modified in alkaline soils by the addition of such compounds as aluminum sulfate (alum.) Ground lime has been used in acid soils to pull the pH level towards neutrality. It may be assumed that under certain conditions, such modifying additives may also be effective in improving the pH of limited areas within a disposal facility, if planting is planned.

C. Special measures

Topsoil storage and use in planting, although not likely to be planned for coastal CDMD sites, should be anticipated for inland sites. Topsoil is the complex layer of undisturbed native soil that overlies the subsoil. It normally contains a good balance of nutrients, soil particle sizes, and organic matter necessary for optimum plant growth. Any topsoil located on the site of a proposed CDMD facility should be used to its fullest in the landscape development program. All site topsoil, prior to retention structure construction, should be stripped (avoiding mixture with the subsoil) and stored adjacent to the facility. It is ideally handled when moderately moist. Storage of the material in high mounds as well as its compaction by heavy machinery should be avoided. If stored over long periods of time, grasses or legumes should be planted for root development to maintain an optimum soil texture and nitrogen level.

Prior to the mixing of the topsoil with the top layer of the dredged material, soil samples should be taken and the proper nutrient addition taken into account.

<u>Protection of existinq vegetation-</u> from machinery during construction and operation of the CDMD facility should be provided. Adequate measures, such as the use of barriers, and the careful location of access for equipment should be promoted to protect and enhance existing trees and shrubs deemed worthy of saving. Careful control should also be instituted in the replacement of vegetation injured as a result of negligence.

3. Plant Establishment

Little research has been conducted to date on the relative effectiveness of different planting and seeding techniques for given tree and shrub species on dredged material. In view of this state of knowledge, care should be exercised in selecting, monitoring, and comparing alternative techniques and measures. In time, experience and the reporting of research and project results should permit more carefully defined recommendations.

a. Planting season

Plant establishment should be scheduled during normal, optimum planting seasons rather than at the end of disposal operations, if such would require off-season planting. Planting or seeding concurrent with disposal or retention structure construction should be encouraged and can be made practicable through normal coordination between operations contractors or personnel and planting contractors or personnel. Optimum planting seasons are as follows:

Deciduous trees and shrubs	early spring
Conifers and evergreen shrubs	spring, autumn
Container and pot-grown plants	early spring, autumn

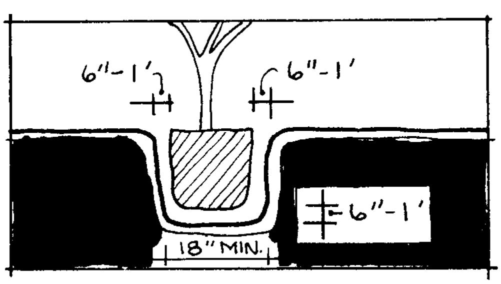
On light soils and in drier parts of the country, planting is best in the autumn, when droughts are not likely to be followed by hot weather. In such areas, autumn planting favors greater root development relative to the plant's foliage mass and will take greater advantage of ground water in the following spring and summer. Since roots may rot in winter in heavy and wet soils, planting on such soils and in northern areas is best in spring when the soil becomes warmer and favorable root development can take place. Planting should be postponed when the dredged material is wet or waterlogged, when the ground is frozen, and during periods of drought or drying winds. The importance of adequate preparation of ground prior to planting, discussed above, should not be overlooked.

b. Bare-root plants

All plants must be protected from moisture loss during shipment from the nursery prior to planting. Upon arrival and until actual planting, roots should be protected, and the entire plants kept in the shade and away from drying winds. Heeling in is one method that reduces the loss of moisture and is particularly useful for protecting bare-rooted plants. The plants are laid in an open trench at an angle to the ground and the roots are covered with moist earth. Moist sawdust, burlap, or tarpaulins may also be used. Care should be exercised in uncovering roots prior to planting.

c. **Balled and burlapped plants**

In contrast to bare-root plants, evergreens, large shrubs, and trees can be stored and planted with the earth intact around the roots. The earth is kept in place by burlap tightly bound with twine or rope. Care should be taken not to crack or dry the root ball. The planting procedure is the same as that for pot or container-grown plants, which include seedlings grown in disintegratable containers such as peat pots, large shrubs or small trees grown in metal or plastic cans measuring up to a few feet in diameter, and semi-mature trees grown in wooden boxes measuring at least several feet on a side. When planting plant materials of these types, the holes should be excavated to a depth and width six inches to one foot greater than the diameter of the root ball.

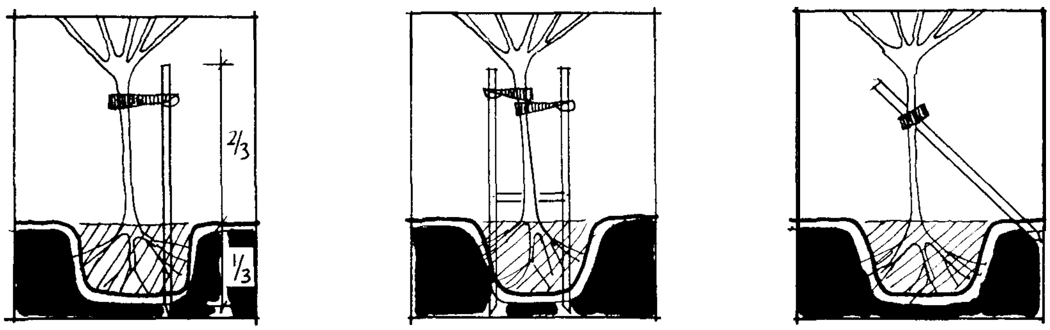


Small tree planting holes

These dimensions allow the planting medium to be broken up to permit air and water penetration and to be supplemented with some ameliorant such as sand, peat, or topsoil, if necessary.. Simple hand methods using a shovel and/or hand auger may be employed. Mounted augers within a twelve-foot radius of their tractors may also be used to dig holes up to eighteen inches in diameter. Plants should be set plumb in their planting hole, kept to the same ground level as they were while growing in the nursery. The containers are, of course, removed prior to this step unless they are of a disintegratable nature; balled and burlapped plants require removal of the ropes and a loosening of the burlap. A few inches of mulch may then be added to the bottom of the planting hole prior to planting. As discussed previously it is highly recommended that a slow-release fertilizer be used.

d. Staking and guying

With large or semi-mature trees six feet or greater in height, artificial supports may be used as temporary measures and should be eliminated when their usefulness has been terminated.



A single vertical stake may be used in some conditions. Double vertical stakes set perpendicular to the prevailing winds with ties to the tree trunk may also be used. Double-staking is by far the better method, especially if the plants are fast growing and soft wooded, because natural conditions that allow the trunk movement necessary for eventual independent support are emulated. A single stake may also be set at a 45° angle against the prevailing winds. All vertical stakes should be cut to just below the crotch of the tree to minimize injury to the branch structure (Tandy, 1970).

When staking and guying are used, the means of attachment to the tree should prevent abrasion of the bark. Ties must also be expandable so that the trunk or branches will not be strangled.

e. Seed

Seeding grasses and trees may be accomplished after the initial grading preparation is completed, the dredged material having been tilled and disced to a smooth texture. Seeding may be practical by hand on remote small areas. Hydroseeding may be used to spread seed as far as 200 feet from the source or farther if attachment hoses are employed. Manufacturers claim such machines are capable of seeding one acre of land in approximately sixteen minutes. Their practical use on large sites is therefore quite evident and should be investigated in dredged material site applications. In addition, because of their ability to broadcast materials to great distances, hydroseeders may possibly be employed from a barge or other watercraft. This may prove advantageous for use with retention structures not capable of allowing vehicular access. Modern techniques now can broadcast a mixture of seeds, fertilizer, and mulch, permitting a one-step application. Because of the added ease offered, this technique should be investigated further. Hydroseeding or mulching material may also be colored to aid the operator in visually following the broadcast seed. In addition, various soil stabilizers may be added to the seed/mulch slurry to improve erosion control until proper plant growth takes over. A testing of these techniques under the adverse conditions of CDMD operations should be fully investigated.

Applied mulch aids the seed by retaining needed moisture at the surface. It also controls the erosion to some degree. On steep banks with slopes greater than 3H on 1V, a deeper layer of chips may be required. This would necessitate another seeding technique called spot seeding. Mulch is first spread to a depth of 3-4 inches, uniformity not being critical, prior to planting the seeds under the mulch. Various hand tools may be used that enable the injection of selected amounts of seeds at a time. The area is simply raked clear of mulch, seeded, and then remulched to a depth of approximately one inch. The spacing interval will be dependent on the plant species (Zak et al., 1972).

f. Cuttings

Roots of plants that naturally spread by root suckers may be cut approximately into three-inch sections and used for planting. Mulching and planting techniques similar to those discussed for spot seeding are used. Plants suitable for propagation by root cuttings include Robinia fertilis (Bristly Locust) and Comptomia peregrina (Sweet Fern) (Zak et al., 1972). Cutting may also be made from the branches of soft-wooded trees such as Salix spp. (Willow) and Populus spp. (Poplars). Particularly suited for wet areas, these suckers may be placed in the wet dredged material. As with all soft-wooded, water-loving plants, care should be taken not to establish them in areas where roots could cause interference with building structures, filters, or piping.

g. Sprigging

Underground sections, rhizomes, of some plants are capable of rooting and may be hand broadcast, plugged, or mechanically planted. Plugging involves planting a cylindrical portion of soil containing the rhizome.

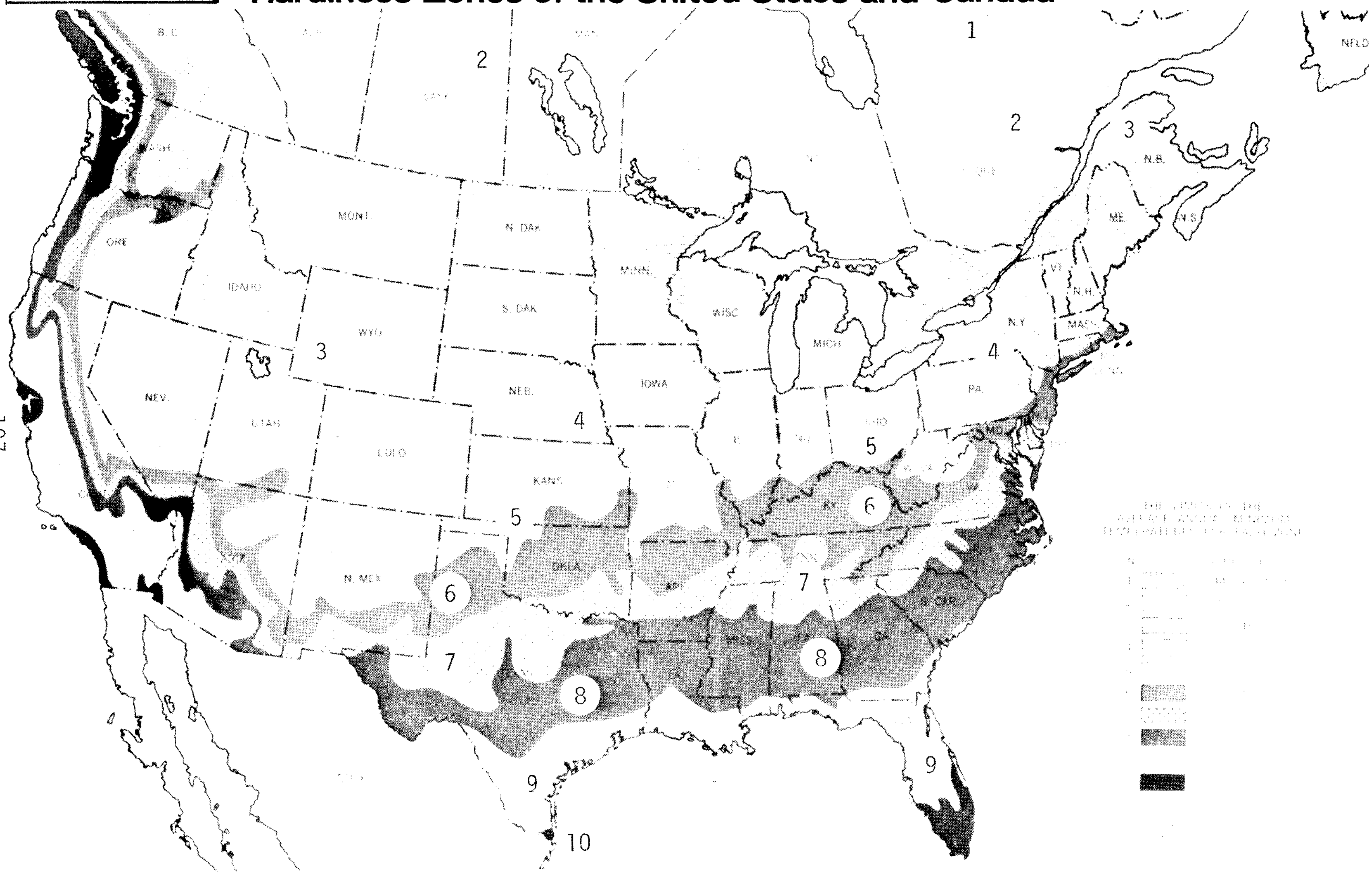
Herbaceous plants are commonly planted by means of sprigging techniques. Zoysia spp. and Cynodon dactylon (Bermuda Grass) are examples of plants capable of being sprigged.

h. Maintenance

Watering, after initial application during planting, will probably not be needed for smaller plant forms, especially those which are drought tolerant. Planting done in the spring will require careful attention to spring rains. If the rains are minimal, a second watering may be necessary. Mature vegetation will require a more frequent and scheduled watering program. Water trucks or mobile pumps on freshwater sites should be employed where possible. Mulching is useful since it promotes water retention and controls weed growth. An application and maintained level of three to four inches of mulch around the base of the plant should be adequate. Weed growth may require control if the induced plants are being deprived of needed moisture and nutrients. The presence of grasses may be beneficial in that they can provide shade for young plants, preventing sunburn. In any case, weeds and grasses should be cut back in the fall to prevent their rainfall-laden weight from collapsing young plants.

Fertilizing plants will probably be necessary in the first several years of establishment. Thinning may also be used to achieve the.desired level of stock density.

Figure: 2 **Hardiness Zones of the United States and Canada**



Omission of hardiness zones in Plant Lists indicates exotic species for which hardiness zones have not yet been established.

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Table: 7 Plant List: Trees & Shrubs

Zone of Hardiness:		Refer to Figure 2
Height (Ft):		Mature plant height in feet
Growth Rate	F:	Fast
	M:	Medium
	s:	Slow
Optimum Soil Condition:	Ac:	Acidic
	Al:	Alluvium
	Ak:	Alkaline
	B:	Brackish
	Cl/Ml:	Clay/Marl
	G:	Gravel
	H:	Humus
	L:	Loam
	Mst:	Most types
	M:	Mud
	Pt:	Peat
	Po:	Poor
	Ps:	Porous
	Ri:	Rich
	Rk:	Rocky
	Sl:	Silt
	Sn:	Sand
Optimum Root Zone Moisture	M:	Moist
	I:	Intermediate
	D:	Dry
Drought Tolerance	Dt:	Drought Tolerant
Salt-Spray Tolerance	St:	Salt-spray Toler-ant
Planting Techniques	cu:	Cutting
	Di:	Division
	Rt:	Root Stock
	Sd:	Seeds
	Sk:	Suckers
Foliage/Trunk Charac-teristics	a/c:	Autumn Colors
	D:	Deciduous
	E:	Evergreen

NOTE: The reader is cautioned not to consider the plant list as a definite index of species adaptable to CDMD sites, since many of the species have not yet been observed in situ; their adaptability should be considered potential until adequate field experience is obtained. Additional species in time may also be identified and added to the list. Suitable local horticultural and soils expertise should be enlisted by District Engineers prior to actual plant selection.

Sources for Tables 7, 8 and 9 are presented in the Bibliography.

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height, ft.	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Acacia farnesiana	Sweet Acacia	8	10	F	Sr	M	Dt	St	Sd	D-small leaflets thorny, similar to wrightii	
Acacia latifolia	Wattle	9	10	F	Sr	M	Dt	St	Sd	D	
Acacia longifolia floribunda	Gossamer Sydney Acacia	10	20			D	Dt			E-fine foliage, spreading	
Acacia wrightii	Catclaw	8	30	F	St.	M	Dt	St	Sd	D-leaves bright green and hairy	
Acanthocereus	Dildoe Cactus	9	30		Sn. Ml	D			Di	E	
Acer negundo	Box-elder	2	60	F		D	Dt			D-no autumn color	
Acer platanoides	Norway Maple	3	90	F	L	I				D-good shade tree	
Acer pseudoplanatus	Sycamore Maple	5	90					St		D-no autumn color	
Acer rubrum	Red Maple	3	120	F	Yst	M	Dt		Sd cu	D-dense, autumn color brilliant red	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Acer **saccharum**	**Sugar Maple**	3	120	M	**L**	I			Sd Cu	**D-dense, autumn color yellow to red**	 1"= 120'
Acer **tataricum**	**Tatarian Maple**	4	30	M		I				**D-dense, fine bright green foliage, autumn color yellow/red**	
Adenostema fasciculatum	**Chamise**	7	**10**	- F	Sn- **G**	D	Dt		**Sd cu**	**E-small needle shaped heathlike leaves**	
Agave **americana**	**Century Plant**	8	6	S	Sn- **L**	D	Dt		**Sk**	**E-trunkless, stiff spiny suc-culent leaves**	
Aesculus hippocasta-**num**	**Horse Chestnut**	3	75	F	**L**	I			**Sd**	**D-weak wood**	
Ai**lanthus altissima**	**Red Fruited Tree of Heaven**	4	60	F	1st	1-D		St	**Sd cu**	**D-coarse texture** diecious	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height ft.	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Albizia julibrissin	Silk Tree	7	36		Po				Cu	D	
Alnus glutinosa	Black Alder	3	80	F	L	M			Sd cu	D-dark green, leaves stay on tree into fall	
Alnus maritima	Seaside Alder	6	30	F	Sn-L	M		St	Sd cu	D-lustrous qreen above, yellow stem broad leaves, bark smooth and light grey	
Amelanchier canadensis	Service Berry	3	30	M	L	M	Dt	St	Sd	D-grey bark, red orange autumn color	
Amyris elemifera	Sea Amyris	10	15		Sn	I				E	
Aralia elata	Japanese Angalica	3	45	M	Ri	I	Dt		Sd Rt	E-dark glossy, open, coarse	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height ft	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Arbutus menziesi	Pacific Madrona	7	75	M	Sn-G	I	Dt		Sd cu	E-dark glossy green	
Arctostaphylos manzanita	Manzanita	10	13	S	Sn-G	I	Dt		Sd cu	E-dark green, trunk brown-red	
Arctostaphylos pumila	Dune Manzanita	10	½	S	Sn-G	D	Dt		Sd cu	E-dark green, trunk brown-red	
Arctostaphylos tomentosa	Shaggy Bark Manzanita	10	6	S	Sn-G	D	Dt		Sd cu	E-dark green trunk shaggy bark	
Arctostaphylos uva-ursi	Bear-berry	2	½	S	Sn-G	D	Dt		Sd cu	E-autumn color bronze	
Atriplex acanthocarpa	Orach	8	4		Sn	I	Dt	St	Sd	D	
Avicennia nitida	Black Mangrove	9	30		Sn-L	M		St		E-oblong curled curled leaves, trunk dark brown-red, scaly	
Baccharis angustifolia	Groundsel Bush	10	8	F	Sn-L	M		St	Sd cu	E-light green	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height ft	Growth Rate	Optimum Soi Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Baccharis halimifolic	Sea-myrtle	4	12	F	Sn-L	M		St	Sd cu	D-dark green leathery leaves, autumn color bronze to grey-green	
Baccharis pilularis	Fingerling	10	½	F	Sn-L	I	Dt		Sd cu	E-light green prostrate	
Bambusa	Bamboos	10	100	M	L	1-D			Di	E	
Berberis thunbergii	Japanese Barberry	5	8	F	Sn-L	M	Dt		Sd cu	D-autumn color scarlet, winter twigs thorny, red fruit	
Betula davurica	Dahurian Birch	4	60		G					D-bark peels off in regular pieces	
Betula papyrifera	Paper Birch	2	90	F	Sn	I			Sd	D-open, autumn color yellow, bark white, peels off in sheets	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height ft	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Betula populifolia	Grey Birch	5	30	F	G	M	Dt		Sd	D-open, autumn color yellow, bark white with triangular black markings	
Borrichia arborescens	Sea Ox-eye	10	2	M	Sn-L	M		St	Sd	D	
Borrichia frutescens	Sea Ox-eye	8	3		Sn-L	M		St	Sd	D	
Broussonetia papyrifera	Common Paper-Mulberry	6	48		PO				su	D grey bark	
Bucida buceras	Ox Horn	10	75	M	Sl-M	M				E-leathery leave!	
Bumelia angustifolia	Buckthorn	10	25	M	Sn	D			Sd	D	
Bumelia celastrina	Saffron Palm	9	24	M	Sn	I		St	Sd	E	
Bumelia lanuginosa	Gum Bumelia	5	40	M	L	I		St	Sd	E-bark dark grey to black and scaly	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Bumelia reclinata	Buckthorn	9	10	M	Sn	I		St	Sd	E	
Bumelia tenax	Tough Bumelia	9	27	M	Sn	M			Sd	E-similar to lanuginosa, spiny, shiny red hairs under leaves and on twigs	
Bursera simaruba	Gumbo-limbo	10	60	M	Pt-L	I			cu	D-bark smooth an red-brown	
Byrsonima lucida	Locust Berry	10	3	M	Ak	D			Sd	E	
Callicarpa americana	Beauty Berry	10	6	M	L	I			Sd cu	D-leaves white beneath	
Capparis jamaicensis	Jamaica Capper	9	20		Sn	M			Sd cu	E-leaves yellow-green above, brown scales below	
Carya floridana	Florida Hickory	10	75	S	Sn				Sd	D	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Carya glabra	Pignut Hickory	4	120	S	Sn-L	D	Dt		Sd	D-dense, autumn color yellow	
Carya ovata	Shagbark Hickory	4	120	S	Sn-L	D	Dt		Sd	D-dense, golden brown, bark flakes off in plates	
Casasia clusifolia	Seven-year Apple	10	10		Sn	M		St		E-numerous branches, leaves clustered	
Cassia aspera	Partridge Pea	9	2		Sn	I	Dt		CU	D-densely branching	
Cassia brachiata	Sensitive Pea	10	6					St	cu		
Castanea pumila	Chinquapin	5	50	M	PO	D	Dt		Sd	D	
Casaurina stricta	Coast Beefwood	10	30		B			St		E	
Ceanothus dentatus	Dwarf Ceanothus	10	3	S	Sn	I	Dt		Sd cu	E-dense	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height ft	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Celtis australis	European Hackberry	6	75			D	Dt			D round, spreading habit	
Celtis occidentalis	Hackberry	4	70	F	Mst	I			Sd cu	D-dense	
Celtis pallida	Hackberry	7	6	F	Mst	I			Sd cu	D-spiny shrub	
Celtis pumila	Hackberry	5	12	F	Mst	I			Sd cu	D	
Ceratiola ericoides	Rosemary	9	8	M	Sn	D			Sd	E	
Chrysobalanus icaco	Coca-plum	10	25		H-Sn	M			Sd cu	E-leathery leaves	
Citharexylum fruticosum	Fiddlewood	9	30	M		D				E	
Clethra alnifolia	Summersweet	3	10	M	Sl	M			Sd cu	D-autumn color yellow/orange	
Coccoloba aurifolia	Pigeon Plum	10	45	M	Sn	D			cu	E-large leaves	
Coccoloba uvifera	Sea Grape	10	20	M	Sn	D	Dt	St	cu	E-large leaves	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height ft	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Coccothrinax agentata	Silver Palm	10	20	M	Sn-L	M		St		E-fan palms	
Cocos nucifera	Coconut Palm	10	80	M	Sn	D	Dt	St	Sd	E-graceful but coarse, long leaves, trunk long and crooked	 1"= \ 20'
Codiaeum orgyanthemus	Croton	10			Mst				Sd cu	E-thick lobed leaves	
Codiaeum linearis	Narrowleaf Croton	10	6		Mst				Sd cu	E-thick lobed leaves	
Codiaeum fergusoni	Croton	10			Mst				Sd cu	E-thick lobed leaves	
Codiaeum punctatus	Silverleaf Croton	10	3		Mst				Sd cu	E-thick lobed leaves	
Codiaeum spp.	Croton	10	6		Sn	I	Dt	St	Sd cu	E-thick lobed leaves	
Colubrina aborescens	Coffee Colubrina	10	25		I-L	M				E-leaves dark green, lustrous	
Conocarpus erecta	Button Mangrove	9	50		Mst	M		St		E-smooth silky foliage	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height, ft.	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Cordia sebestina	Geiger bush	10	35	M	Sn-H	I			Sd Cu	E-rough dark brown bark, undulate leaf margins	
Cornus florida	Flowering Dogwood	4	40	S	Mst				cu	D-dense, lus-trous, autumn color scarlet	
Cornus nuttalii	Coastal Dogwood	7	75	S	Mst	M			cu	D-dense	
Cornus stolonifera	Red osier	2	10	M	L	M			cu	D-rough leaves, reddish twiggs	
Corylus americana	Hazelnut	3	10	M	Yst	M			Sd	D-dense, coarse leaves	
Cryptomeria japonica	Cryptomeria	5	50						Sd	E-pyramidal habit., sharp needles, reddish bark	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height ft	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Crataegus crus-galli	Hawthorn	4	36	S	Cl	M	Dt		Sd Cu	D-rounded top, thorny, dense, lustrous, autumn color orange/ scarlet	
Cupressus goveniana	Tower Cypress	9	25		Sn-Cl	D	Dt			E-dark green, bark red-brown scaly and ridged	
Cupressus macrocarpa	Monterey Cypress	7	75	F	Sn-Cl	D	Dt	St		E-scalelike, dark blue-green, bark brown-grey and ridged	
Cyrilla racemiflora	Titi	5	30	M	L	M			Sd cu	E-bark lustrous red-brown, leaves shiny and leathery	
Dalbergia brownei	Rosewood		9		Sn-L		Dt	St	Sd cu	E-some climbers	
Dalbergia ecastophyllum	Shore Bean Shrub	10	9		Sl-H	M			Sd cu	E-trailing branches, leaves pinnate	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height ft	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Dipholis salicifolia	Willow Bustic	10	75		Sn-H	I				E-pinnate leaves	
Drypetes lateriflora	Guina Palm	10	25		H-Si	I				E-alternate leathery leaves	
Elaeagnus angustifolia	Oleaster	2	20		Sn-L	D	Dt	St		D-dull grey green; dense; trunk crooked with peeling bark	
Elaeagnus commutata	Silverberry	3	12		Sn-L	D	Dt			D-branchlet red brown scales, leaves silvery	
Erica tetralix	Heath	3	2	S	Pt	M			Sd cu	E-needlelike woody, grey	
Ericameria ericoides	Heath Composite	10	2.5	S	Sn	I		St		E-heathlike	
Erithalis fruticosa	Dune Berry	10	9		Sn	D		St		E-leaves dark green glossy, smooth stems	
Escallonia rosea	Escallonia	10	10	F		M			Sd cu	E-glandular viscid stout branches	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height ft	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Eucalyptus spp.		9	00		Sn-L	D	Dt	St	Sd	E	
Eucalyptus umbellata	Horn Cap	9	50		Sn-L	D	Dt			E	
Eugeni a axillaria	White Stopper	9	30	F	Sn	M,I				E-lonp shiny leaves, dull underside	
Eugeni a buxifolia	Boxleaf Stopper	9	36	F	Sn	M,I				E	
Eugenia dicrana	Twinberry Stopper	9	25	F	Sn					E	
Exostema caribaeum	Princewood	10	25		Hu	M				E-shrub or small tree with glabrous stems	
Fatsia japonica	Aralia	7	20		Sn	I			Sd Cu	E	
Ficus aurea	Strangler Fig	9	60	F	M	M				E-engulfs tree stems	

Plant. List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Ficus laevigata	Wild Fig	10	36		H	M				E-elliptical or ovate, slabrous leaves	
Forestiera porulosa	Florida Privet	9	10		H	M		St		E-glabrous stems evergreen, leaves elliptic	
Forsythia suspensa	Weeping Forsythia	4	9	F	Ac	D,M	Dt		Cu	D-weeping branch yellow flowers	
Fraxi nus americana	White Ash	3	120	F	Sl	M			Sd	D-dense foliage autumn color purple, yellow	 1"= 120'
Fraxinus nigra	Black Ash	3	75	M	L	M			Sd	D-dense foliage	
Fraxinus pennsylvanica	Green Ash	2	60	F	Ak	M			Sd	D-dense foliage, autumn color yellow	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Fraxinus velutina	Velvet Ash	7	45		Ak	D				D-open foliage	
Gaylussacia baccata	Black Huckle-berry	5	1.5		Sn	M			Sd Di	E	
Gossypium religiosum	Tree Cotton	10	4	S	L	M			Sd	D-bushy, much branched	
Grevillea robusta	Silk-oak Grevillea	10	50		Sn					E-long feathery leaves, white silky undersur-face	
Guaiacum sanctum		10	30		Sn	I			Sd	E-leaves with 3-4 pairs of obovate sub-sessile leaflets	
Guilandina bondoc	Nicker-nut	10	12		Hu	M				l-leaflets oblong-oval	
Guilandina crista	Wood Gossip	10	12		Hu	M				l-shrub scraggly, reclining over vegetation, vis-cid pubscent and prickly with	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Hibiscus syriacus	Shrubalthea	4	21	M	Sn L	)-M	Dt		Cu	D-curved spines throughout	
Hibiscus tiliaceus	Sea Hibiscus	10	25	F	Sn	ᐱ,I	Dt	St	Sd cu	D	
Hippophae rhamnoides	Common Sea-buckthorn	3	30							D-greyish green willow-like leaves	
Hudsonia tomentosa	False Heather	4	1	F	Sn	D	Dt	St		E-dense, scale-like leaves	
Hydrangea arborescens	Shrub Hydrangia	4	10	M	Ps	I	Dt		cu	D	
Hypericum aspalanthoides	Sand Cypress	4	3	F	Sn	D			Sd cu	E	
Hypericum fasciculatum	Sand Cypress	4	2	F	Sn	D			Sd cu	E	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Icacorea **paniculata**	**Yarlberry**	10			H	I				**E-leaves on stout petioles, flowers in terminal dense panicles, light colored smooth stems, shrub or small tree**	
Ilex glabra	**Gallberry**	3	20	M	**Sn**	M			**Sd** Cu	**E-lustrous, dark leaves**	
Ilex opaca	American **Holly**	5	40	M	Sn-**L**	M	Dt		**Sd cu**	**E-dense spiny leaves, not lus-trous; bark smooth light** grey	
Ilex vomitoria	Yaupon	7	**24**	M	Sn-**L**	M	Dt	St	**Sd cu**	**E-long, lustrous leaves**	
Ilex verticillata	Winterberry	3	9	M	**L**	M			**Sd cu**	**D-autumn color yellow, red fruit borne with qreen leaves**	
Jacquinia keyensis	Joewood	10	15		Sn-Sl	M,I				**E**	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height, ft.	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Juniperus communis	**Common Juniper**	2	**10**	M	Sn-Sl	D	Dt			**E-needlelike, brown in winter, spreading**	
Juniperus conferta	**Shore Juniper**	5	1		Sn	I	Dt	St		**E-needlelike, blue/green, spreading**	
Juniperus excelsa stricta	**Greek Juniper**	7	**60**	S						**E-narrow, pyramidal habit**	
Juniperus lucayana	**West Indies Juniper**	9	**50**							**E-pyramidal habit small, pointed leaves**	
Juniperus silicola	**Southern Red Cedar**	8	**90**		**Sn**	D				**E-leaves** scale-**like, opp. or 3-4** whorled	
Juniperus procumbens	**Creeping Juniper**	4	2.5			I				**E-wide-spreading, mound-like shrub, leaves needle-like, bluish, in whorls of 3**	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Juniperus virginiana	Eastern Red Cedar	2	90	S	G,L	I				E-scalelike bark shredding in long strips	 1" = 120'
Kalmia latifolia	Mountain Laurel	4	30	S	Ac	M	Dt		Sd Cu	E	
Keteleeria fortunei	Fortune Keteleeria	7	90			D				E-pyramidal habit, needlelike foliage	
Koelreuteria paniculata	Golden-rain Tree	5	30		Mst				Sd	D-no autumn color yellow summer flowers	
Krugiodendron ferreum	Ironwood	10	30		Hu	M				E-leaves ovate or elliptical, dark green above, paler beneath	
Lagunaria patersonii	Paterson Sugar-plum Tree	9	50					St		E-pyramidal habit	
Lantana involucrata	Lantana	9-10	6		L	I			Sd Cu	E	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Lantana camara	Common Lantana	8	6		H	I				E-smooth shrub, usually armed with small or stout recurved prickles	
Lantana horrida		6	6			D			Sd	E-shrubs, leaves opp., lanceolate to broadly ovate	
Larix decidua	European Larch	5	100	S	Pt-L	M				D-leaves soft bright green, bark dark grey-ish brown	
Larix laricina	Eastern Larch	1	60		Mst	M				D-open foliage	
Larix leptolepis	Japanese Larch	5	90	M-S	Pt-L	M				D-leaves soft bluish green, bark grey peelin	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Lavatera assurgentiflora	Tree Mallow	10	10		Sn				Sd cu	D	
Leiophyllum buxifolium	Sand Myrtle (Box)	5	1.'		Ac	M			Sd cu	E-lustrous, brown/green in autumn	
Lespedeza bicolor	Shrub Lespedeza	4	10		Sn				Sd	D-upright growth late summer pea-like flowers, compound leaves, branchlets hairy	
Leptospermum scoparium	Tea Tree	9	20		Sn	D	Dt	St	Sd cu	E	
Libocedrus decurrens	California Incense Cedar	5	35		Ri	M				E-narrow columnar habit	
Ligustrum lucidum	Glossy Privet	7	30	F	Mst	I	Dt	St	Sd Cu Di	E-shiny leaves	
Ligustrum ovalifolium	Privet	5	15	F	Mst	I			Sd Cu Di	D	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height ft	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Liquidambar styraciflua	Sweetgum	4	i25							D-broadly pyramidal, scarlet autumn color	
Lonicera involucrata	Bearberry	2	3	M	L	I			Sd Cu	D	
Lonicera maackii	Amur Honeysuckle	4	15	M	Mst	I	Dt			D-branchlets hairy, leaves dark green	
Lonicera morrowii	Honeysuckle	4	6	M	L	I				D-dense foliage	
Lyonia ferruginea	Rusty Lyonia	9	15		Ac	1,I,)				E	
Lyonia lucida	Petter Bush	7	6		H	I				D-erect shrub with evergreen leaves, branches smooth	
Lysiloma bahamensis	Wild Tamarind	10	60		Ac	1,I,)				E	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Maclura pomifera	Osage-Orange	5	60	F			Dt			D-open foliage, yellow a/c	
Magnolia grandiflora	Magnolia	7	90	F	L	M	Dt	St		E	
Magnolia virginiana	Sweet Bay	5	60		Yst	M				D-green foliage, white underside	
Maytenus boaria	Chile Mayten	9	35					St		E-dense, light green foliage	
Melaleuca leucadendra	Cajeput Tree	10	40							E-slender, up-right habit	
Melia azedarach	Chinaberry	7	45		Mst		Dt		Sd Cu	D-dense foliage	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height ft	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Metopium toxiferum	Poison Wood	9	43		Sn	I				E-Resinous sap. Leaves with 3-7 ovate, corria-ceous leaflets	
Myrica californica	Wax-myrtle	7	36			M			Sd, Sk	E-lustrous, bronze	
Myrica cerifera	Wax-myrtle	6	20	M	Sh	M	Dt	St	Sd, Sk	E	
Myrica gale	Sweet-gale	4	5	S	Pt	M			Sd, Sk	D	
Myrica pensylvania	Bayberry	4	9	S	Sn-	M	Dt		Sd, Sk	D-dull green,se-mi-evergreen	
Nectandra corlacea	Lancewood	10	30		H	M-I				E	
Nerium oleander	Oleander	7	20			I	Dt	St	CU	E-bamboolike	
Nyssa sylvatica	Black Gum	4	90	5	-, Pt	M				D	
Olea europaea	Common Olive	9	25		Mst	D	Dt			E-gray/green foliage, sil-very beneath	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Opuntia austrina	Prickly Pear	9	½			D	Dt		Sd, Cu	E-bright green, flat broad fleshy pads	
Opuntia humifusa	Prickly Pear	4	½	S	Sn Rk	D	Dt		Sd, Cu	E-spreading flat broad pads	
Opuntia lindhemeri	Prickly Pear	8	12	M	Sn G	D	Dt		Sd, Cu	E-spiny flat broad pads	
Opuntia serpentina	Cholla	9				D	Dt		Sd, Cu	E-cylindrical branches, spiny	
Osmanthus americanus	Wild 01 ive	7	70							E-leathery leaves bark dark brown and ridged	
Pandanus babtitsii	Screwpine	9		F		M	Dt	St	Sd, Sk	E-stiff, linear prickly edged leaves	
Parkinsonia aculeata	Jerusalem Thorn	9	30		Sn					D-open habit, green bark	
Paspalum caespitosum	Bunch Millet	10	1-1½		H	I				grass	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Persea **borbonia**	**Red Bay**	8	**40**	M	Sl, Pt	M	Dt	St	Sd, Cu	**E**	
Persea **littoralis**	**Shore Bay**		**60**		**Mst**	M			Sd, Cu	**E**	
Picea abies	**Norway Spruce**	2	**150**	M	Sl, **L**	M				**E-dense, dark green needles**	 1"= 120'
Picea asperata	**Dragon Spruce**	5	**75**					St		**E-dense foliage light green/blue**	
Picea mariana	**Black Spruce**	3	**40**	S	Pt, L	M				**E-dense needles**	
Picea pungens	**Colorado Spruce**	2	100	F					Sd, Cu	**E-pryamidal** habit	
Picea sitchensis	**Sitka Spruce**	5	150	S	Al, Sl	M				**E-pyramidal habit**	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Picramnia pentandra	Bitterbush	1°			H	M				E-shrubs or small trees	
Pinus attenuata	Knobcone Pine	6	75	F	Sn, G	D	Dt			E-yellow/green	 1"=120'
Pinus banksiana	Jack Pine	2	75	F	Sn	D			Sd	E-2 needles in bundle, open	 1"=120'
Pinus clausa	Sand Pine	9	15	F	Sn, G	D	Dt	St		E-2 needles in bundle, flexible	
Pinus contorta	Lodgepole Pine	3	25	F	Sn	M	Dt		Sd	E-2 needles in bundle, stiff, dark green	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height, ft.	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Pinus **elliottii**	**Slash Pine**	8	**80**	F	**Sn**	M	Dt	St		**E-Z needles in bundle, stiff, dark blue/green**	 1"=120'
Pinus **elliottii** densa	**Southern Slash Pine**	10	**90**		**PO**	D				**E-open cones** with **rounded base. Scaly bark**	
Pinus **nigra**	**Black Pine**	4	**90**	F	**Sn**	D	**Dt**	St	**Sd**	**E-Z needles in bundles, dark green**	
Pinus pinaster	**Cluster Pine**	7	**90**	F	**Sn**			St	**Sd**	**E-Z needles in bundle, twisted** & **glossy green**	
Pinus **radiata**	**Monterey Pine**	7	**60**	F	**Sn**			St		**E-3 needles in bundle, bright green**	 1"=120'

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Pinus rigida	Pitch Pine	4	75	F	Rk		Dt		Sd	E-3 needles in bunch, open	
Pinus serotina	Pond Pine	6-9	75		Sn, L	M				E-3 needles in bundle, flexible dark yellow/green	
Pinus strobus	White Pine	3	150	F	Sn, L	I			Sd	E-5 needles in bundle, soft & flexible	
Pinus sylvestris	Scotch Pine	2	75							E-reddish bark; open, pyramidal habit	
Pinus taeda	Loblolly Pine	5	70	F	Sn Mst	I	Dt		Sd	E-3 needles in bundle, stiff, yellow green	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Pinus thunbergii	Japanese Black Pine	4	90	F				St		E-dense, spreading	
Pinus torreyana	Torrey Pine	8	45	F	Sn	I	Dt			E-5 needles in bundles, stiff, clark green	
Piscibia piscipula	Poisonwood	10	50							D	
Pisonia aculeata	Cock-spur	10			H	M				Dl-woody, climbing vines with branched thorns, ultimate branche curved and very sharp	
Pithecellobium guadalupensis	Black Bead	9	15							E-spiny foliage	
Pithecellobium unguis-cati	Cats Claw	9	50		Sn	D				E-spiny foliage	
Pittosporum crassifolium	Karo		15-30		L		Dt	St	Cu Sd	E	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height ft	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Platanus acerifolia	London Plane	3	120	M	Ri	M				D-large, wide coarse leaves, bark flakes off to greenish/white below	
Platanus occidentalis	American Plane	3	150	M	L	I	Dt		Sd, Cu	D-large, wide, coarse leaves, bark flakes off to greenish/white below	
Populus alba	White Poplar	3	90	F	L	D			Cu	D-upper leaves gray/breen, lower white	 1"=120'
Populus deltoides	Eastern Cotton-wood	2	90	F	Al	M			Sk	D-dense foliage	
Populus fremontii	Fremont Cotton-wood	7	90	F	Ak	D			cu	D-wide habit,open foliage	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Populus heterophylla	Swamp Cotton-wood	5	89	F	Al, Sl	M				D-foliage dark green, paler be-low, bark red/ brown, scaley	
Populus tremuloides	Quaking Aspen	1	80	F	Sn, L	D	Dt		Sk	D-open habit, yellow a/c	
Populus trichocarpa	Black Cotton-wood	3	100	F	Ak				cu	D	
Prosopis glandulosa	Honey Mesquite	8	50	S			Dt			D-bright green feathery foliage	
Prosopis juliflora	Mesquite	7	20	F	Ist	D	Dt		Sd	D-compound leaves	
Prunus caroliniana	Laurel Cherry	8	40		Ist		Dt	St	Sd	E	
Prunus depressa	Beach Cherry	3	5		Ist				Sd	D	
Prunus lyonii	Catalina Cherry	10	24		Ist				Sd	E	

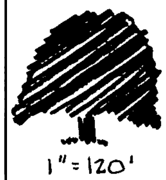
Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height ft	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Prunus maritima	Beach Plum	3	6	M	Mst	D	Dt	St	Sd	D	
Prunus pumila	Sand (dwarf) Cherry	3	5	M	Mst	D	Dt		Sd	D-prostrate	
Prunus serotina	Black Cherry	3	90	M	Mst	M			Sd	D-dense foliage, with flowers	 1''=120'
Prunus serrulata	Japanese Flowering Cherry	5,6	25	F	Mst	I			Sd	D-white/pink flowers	
Prunus virginiana	Choke Cherry	2	25	M	Mst	M			Sd	D	
Pseudotsuga taxifolia	Douglas Fir	4-6	300	F	L	M				E-dense foliage	
Pyrus arbutifolia	Red Chokeberry	4	10	S	L	M				D-hollylike	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristic<	Silhouette
Quercus agrifolia	California Live Oak	9	90	S	L, Gr	D	Dt		Sd	E-dense, a/c purplish/red	
Quercus alba	White Oak	4	90	S	MS t	M			Sd	D-foliage dark green above, silvery beneath; Bark, dark gray	
Quercus bicolor	Swamp White Oak	3	60		M					D-dense foliage, yellow/brown-red a/c	
Quercus chapmanii	Chapmans Oak	9	50		Sn				Sd	D	
Quercus cinerea	Blue-jack Oak	8	40		Sn			St	Sd	D	
Quercus ilex	Holly Oak	9	60	M	L	I		St	Sd	E-holly-like dense dark green foliage; very hardy	
Quercus kelloggi	California Black Oak	7	90		Sn, G					D-dense foliage	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Quercus laevis	Turkey Oak	8	30		Sn				Sd	D	
Quercus laurifolia	Laurel Oak	7	60			M			Sd	E-half evergreen, dark green	 1"=120'
Quercus macrocarpa	Bur Oak	2	70	M	Mst Cl	D	Dt		Sd	D-a/c brown, yellow	
Quercus montana	Chestnut Oak	4	90		Rk	D				I-dense habit, dull orange a/c	
Quercus myrtifolia	Myrtle Oak	8-10			Sn	D			Sd	E	
Quercus rubra	Red Oak	2	70	M	L	M			Sd	D-a/c brown, yellow	 1"=120'

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	'eight (ft.)	rowth Rate	ptimum Soil ondition	ptimum Root one Moisture	rought olerant	alt Spray olerant	lanting echnique	Foliage/Trunk Characteristics	Silhouette
Quercus velutina	Black Oak	4	100	M	L	M-D	Dt		Sd	D-foliage dark green, a/c red	 1"=120'
Quercus virginiana	Live Oak	7	60	M	Sn	M			Sd	E-deciduous in northern limits only	 1"=120'
Quercus virginiana maritima	Dune Live Oak	8-10			Sn	D	Dt	St	Sd	E-small leaves	
Randia aculeata	White Berry	10	10		Sn	I				E-branching spiny shrub or small tree; scrub vegetation	
Rapanea quianensis	Myrsine	10			H	M				E-shrubs or low trees with thick branches; leaves entire, clustered near ends of stems	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Reynosia septentrionalis	Darling Plum	10	30		H	M				E-leaves ovate or ovate-elliptical	
Rhamnus californica	Coffee Berry	9	6			D			Sd, Cu	E	
Rhus copallina	Winged Sumac	4	15	F	Sn	D	Dt		Sd, su	D-lustrous green foliage; a/c scarlet	
Rhus diversiloba	Poisonwood	8	8						Sd, cu	D-erect shrub	
Rhus glabra	Smooth Sumac	2	20		Sn	D			Sd, cu	D-a/c bright red	
Robinia fertilis (hispida)	Bristly Locust	6	1-7	M	su Ac	I	Dt			D-flws., rose-colored or pale purple, freely fruiting; branching shrub, stout stems, red bristles	
Robinia pseudoacacia	Black Locust	3	75	F	Sn, L	I	Dt		Sd, su	D-open foliaqe flowers pea-like and fragrant	 1" = 120'

Plant List: Trees & shrubs

Table 7 (continued

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Rosa rugosa	Rugose Rose	2	6	M	Sn	D	Dt	St	Su	D-dark green foliage, a/c orange	
Rosa virginiana	Shrub Rose	3	6	M	Mst	I			Su, Rt	D-glossy foliage; a/c scarlet, orange; winter twigs red	
Roystonea regia	Royal Palm	10	70				Dt			E-araceful foliag	
Rubus vitifolius	Blackberry	9	6		L				Sd, Cu, Sk	E-briqht green, vinelike	
Sabal etonia	Palmetto Scrub Fan Palm	10	3		Sn	D				E-leaves dark green, filiferous	
Saba l minor	Dwarf Palmetto	9	4		Rk	M	Dt			E-stemless pale green stiff leaves	
Saba l palmetto	Cabbage Palm	8	90		Mst	I				E-coarse, fan-shaped; brownish gray bark	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height ft	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Sageretia minutiflora	Rattan Vine	7-1(			Sn				Sd, Cu	D/E-depending on zone, trailing, spiny, leathery leaves	
Salix babylonica	Babylon Weeping Willow	6	30	F	Sl, Al	M			Cu	D-fine texture foliage	
Salix cordata	Bushy Willow	2	5		Sn	M			Cu	D-clustered shrub	
Salix discolor	Pussywillow	2	20	F	Sl, Al	M			Cu	D-light green foliage	
Salix glaucophylla	Dune (Low) Willow	2	15		Sn	M			Cu	D	
Salix goodingii	Gooding Willow	7	60		Al	M				D-like Black Willow, twigs yellow, leaves narrow lanceolate	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone 40 Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Salix hindsiana	Sandbar Willow	8-9	21		Sn	I				D-erect shrub, gray furrowed bark	
Salix hookeriana	Coast Willow	7	25			M			Cu	D-bright green foliage	
Salix humilis	Small Pussy-willow	3	8		Sn	M			Cu	D-ellanceolate leaves	
Salix interior	Sandbar Willow	2	30		Sn, Al	M			Cu	D-yellow/green foliage	
Salix lasiolepsis	Sand Willow	6	30		Al	M			Cu	D-dark green foliage above, gray below	
Salix lucida	Shining Willow	2	20	F	Al, Sl	M			Cu	D-lustrous dark green foliage	
Salix nigra	Black Willow	3	30	F	Al	M			Cu	D-ridged, dark brown/black bark	
Salix pentandra	Bay-leaved Willow	4	60	F		M			Cu	D-dark green laurel-like foliage	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height ft	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Salix petiolaris	Meadow Willow	2	4			M			Cu	D-purple twigs	
Sassafras albidum	Sassafras	4	125		L	I,D	Dt		Su	D-1,2,3 lobed leaves, aromatic	
Scaevola lumieri	Beach Berry	10	5		Sn	D	Dt	St		E-pantropical	
Schaefferia frutescens	Yellow Wood	10	36		Hu	I				D-tropical, light gray older stems with wart-like clusters, leaves shiny yellow green	
Schinus molle	California Pepper Tree	9	40		PO	D	Dt			E-wide spreading branches	
Schinus terebinthifolius	Brazil Pepper Tree	9, 10	40			D	Dt	St		E-dark green foliage	
Schoepfia chrysophylloides	Whitewood	10	25		H	I				E-young branches pale or white, older bark conspicuously grayish white	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Sequoia sempervirens	Redwood	10	265	F	Sn, L	M				E-flat light green segments of leaves	 1"=360'
Serenoa repens	Saw Palmetto	8	3		Sn	D				Z-foliage dense, creeping	
Solanum verbascifolium	Shrub Solanum	10	30						Sd, Cu	E	
Sophora japonica	Japanese Pagoda Tree	4	75		Mst					I-open, rounded habit	
Swietenia mahogani	Madeira Mahogany	10	60		M					E	
Tamarix gallica	Tamarix	7,8	12	M	Mst	M	Dt	St	Cu	I-blue/green scale-like leaves, small and feather-like; smooth bark	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Taxodium distichum	Common Bald Cypress	4	150		L	M				D-open foliage, feathery, needle-like	
Taxus brevifolia	Western Yew	6	75	S	H	M			Cu	E-needles dark green	 1" = 120'
Thespesia populnea	Seaside Mahoe	10	60			M			Sd	D-pantropical coastal areas	
Thrinax microcarpa	Brittle Thatch-palm	10	30		Sn	D				E-gray bark	
Thrinax parviflora	Jamaica Palm	10	30							E-pale green foliage	
Thuja occidentalis	American Arbor-vitae	2	60							E-columnar habit	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height ft	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Thuja orientalis	Oriental Arbor-vitae	6	50							E-pyramidal, open habit	
Tilia americana	Basswood	5	100	F	L	I			S	D-open foliage; large, coarse leaves	 1"=120'
Tilia cordata	Little-leaf Linden	3	90	F	Mst					D-dense, pyramida	
Tilia euchlora	Crimean Linden	5	60	F						D-glossy, bright green leaves	
Torrubia longifolia	Longleaf Blolly	9	40							E	
Trema lamarckiana	West Indies Trema	10	20		H	M				E-thickly pub-escent twigs. Leaves upper surface rough pubescent	
Tsuga canadensis	Canada Hemlock	3	90	M	Ac	M			S	E-dense, needle-like dark green	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Tsuga heterophylla	Western Hemlock	6	200	M	Ac, L	M			S	E-dense, needle-like	
Ulex europaeus	Gorse	4	5		Mst			St		D-low, densely spiny branched shrub used as sandbinder	
Ulmus fulva	Slippery Elm	3	60		Ri				Sd, cu	D-spreading branches, leaves unequal at base	
Ulmus parvifolia	Chinese Elm	5	50	F						E-dense foliage; red/purple a/c	
Ulmus pumila	Siberian Elm	4	75	F		D			Sk, cu	D-round habit, small leaves	
Umbellularia californica	California Laurel	7	75		Mst					E-dense, round habit	

Plant List: Trees & shrubs

Table 7 (continued)

Botanical Name	Common Name	Zone of Hardiness	Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Vaccinium arboreum	Sparkle Berry	7	27							E	
Vaccinium corymbosum	Highbush Blueberry	4	12	M	Mst	M				D-erect clump of stems	
Vaccinium myrsinites	Shiny Blueberry	9	2		Ac, Sn	I				E-foliage has bristly teeth	
Vaccinium ovatum	California Huckleberry, Blueberry	8	12		Ac		Dt			E-stout branched	
Vaccinium stamineum	Deerberry	4	3	M	Ac	I				D	
Vaccinium vacillans	Low Blueberry	4	3	S	Ac	M	Dt			D-shiny green leaves	
Viburnum lentago	Nanny Berry	2	30	F	L	M			Sd, Cu	D-dense foliage, shiny green a/c purplish red	
Vitex agnus-castus	Chaste Trees	10	12		H	M				D-stems grayish, tomentose with strong, aromatic odor	
Washingtonia filifera	Fan Palm	8	75	S	Ak	M				E-light green foliage	

Plant List: Trees & shrubs

Table 7 (concluded)

Botanical Name	Common Name	Zone of Hardiness	Maximum Height (ft.)	Growth Rate	Optimum Soil Condition	Optimum Root Zone Moisture	Drought Tolerant	Salt Spray Tolerant	Planting Technique	Foliage/Trunk Characteristics	Silhouette
Washingtonia robusta	Mexican Wash-tington Palm	10	90			D	Dt			E-fanshaped, coarse foliage	
Ximenia americana	Hog Plum, Tallowwood	9	30							E:-smooth dark red brown bark	
Yucca aloifolia	Spanish Bayonet	9	25		Sn	D	Dt			E-dark green f'oliage	
Yucca filamentosa	Adams Needle, Silk Grass	5	12	M	Sn	D	Dt			E	
Zamia pumila	Florida Arrow-root Tree, Coontie	10	1½		Sn	M	Dt	St		E:-palm-like leaver	
Zanthoxylum clava-herculis	Toothache Tree	8	50			M			Sd, Cu	E:-prickly trunk	
Zanthoxylum fagana	Wild Lime	10	30	M	H, L	I				EI-shrub, recurved prickles	

Table: 8 Plant List of Additional Trees & Shrubs

BOTANICAL NAME	COMMON NAME
Elaeagnus umbellata var. cardinal	Autumn-olive
Euphorbia buxifolia	Shrub Spurge
Euphorbia ingallsi	Creeping Spurge
Euphorbia innocua	Spurge
Galactia canescens	Milk Pea
Juniperus camara	Juniper
Leucophyllum frutescens	White Leaf
Penstemon cordifolius	Heart-leaved Penstemon
Pithecellobium pallens	Pale Bead
Poinciana gilliesii	Bird of Paradise Shrub
Portulacaria afra	Speckboom
Prosopis reptans	Mesquite
Quercus durata	Leather Oak
Quercus oleoides quatuna	Texas Live Oak
Rubus arenicola	Sand Blackberry
Rumex crispus	Sorrel
Sabina barbadensis	Shore Juniper
Salix sitchensis	Silky Willow
Sideroxylon foetidissium	False-mastic
Soriana maritima	Sea-blite
Stumpfia maritima	Cedar Wood
Tamarix articulata	Tamarix

Table: 9 Plant List of Herbaceous Plant Material

BOTANICAL NAME	COMMON NAME
Abronia fragrans	
Abronia latifolia	Yellow Sand Verbena
Abronia maritima	Red Sand Verbena
Achyranthes maritima	Chatt Flower
Agropyron dasystachyum	Hairy Wild Wheat
Agropyron pungens	Wild Wheat
Agropyron repens	Witch Grass, Couch Grass
Aloe arborescens	Bush Aloe
Amaranthus arenicola	Sand Pigweed
Ammophila arenaria	Marram Grass
Andropogon furcatus	Big Blue Stem Grass
Andropogon gerardi	Big Blue Stem Grass
Andropogon glomeratus	Beardgrass
Andropogon hirtiflorus	Beardgrass
Andropogon littoralis	Coastal Beardgrass
Andropogon scoparius littoralis	Coastal Beardgrass
Andropogon scoparius	Beardgrass
Andropogon virginicus	Broom Sedge
Anemone cylindrica	Thimble Weed
Arenaria peploides	Sea Sandwort
Aristida gyrans	Three-awned Grass
Aristida purpurascens	Three-awned Grass
Artemisia caudata	Wormwood
Artemisia pycnocephala	Sand Sagebrush
Artemisia stelleriana	Dusty Miller
Asclepias tuberosa	Butterflyweed
Aster tortifolius	Desert Aster
Atriplex acanthocarpa	Orach
Atriplex arenaria	Seabeach Orach
Atriplex canescens	Saltbush
Atriplex littoralis	Orach
Atriplex patula	Orach
Batis maritima	Saltwort
Befaria racemosa	Tar Flower
Boerhaavia coccinea	Four O'clock
Brassica geniculatum	
Brassica nigra	Black Mustard
Bromus inermis	Hungarian Brome Grass
Cakile endentula	Sea Rocket
Calamovilfa longifolia	Dune Grass
Calochortus venustus	Butterfly Mariposa
Canavalia lineata	Sea Bean, Bay Bean

Table 9 (continued)

BOTANICAL NAME	COMMON NAME
Capparis cynophallophora	Bay-leaved Cappep
Carex arenaria	Sedge
Carex kobomugi	Japanese Sedge
Carex silicea	Sand Sedge
Cassia fasciculata	Dune Senna
Castilleja litoralis	Coastal Paint Brush
Cenchrus pauciflora	Sand-spur
Cenchrus tribuloides	Sand-spur
Centaurea solstitialis	
Chenopodium album	Pigweed
Chenopodium ambrosioides	American Wormseed
Chloris glauca	Finger Grass
Chloris petraea	Finger Grass
Chrysopsis graminifolia	Golden Aster
Chrysopsis mariana	Golden Aster
Cirsium pitcheri	Beach Thistle
Cnidoscolus stimulosus	Nettle
Conradina grandiflora	Shrub Mint
Coreopsis gigantea	Tree Coreopsis
Corispermum hyssopifolium	Bugseed, Tumbleweed
Coronilla xaria	Crown Vetch
Cynodon dactylon	Bermuda Grass
Cyperus brunneus	Sedge
Cyperus lecontei	Coca-grass
Digitaria filiformis	Finger Grass
Digitaria sanguinalis	Finger Grass
Distichlis spicata	Spike Grass
Echinocystis fabacea	Wild Cucumber
Elymus arenarius	Sea Lymegrass
Elymus arenicola	Sea Rye Grass
Elymus canadensis	Wild Rye
Elymus flavescens	Yellow Rye Grass
Elymus mollis	Dune Grass
Elymus robustus	Wild Rye
Encelia californica	Bush Sunflower
Equisetum arvense	Horsetail
Eragrostis amabalis	Love-grass
Eragrostis hypnoides	Love-grass
Eragrostis oxylepis	Love-grass
Erigeron canadensis	Fleabane
Eriogonum latifolium	Buckwheat
Ernodea litoralis	Coastal Ernodea
Eryngimum maritimum	Sea Holly
Erysimum capitatum	Wall Flower
Erythrina arborea	Coral Bean
Eschscholzsia californica	California Poppy

Table 9 (continued)

BOTANICAL NAME	COMMON NAME
Eugenia myrtoides	Box Leaf Stopper
Euphorbia polygonifolia	Seaside Spurge
Festuca arenaria	Sand Fescue
Festuca arundinacea	Reed Fescue
Festuca rubra	Red Fescue
Fimbristylis castanea	Sand Rush
Franseria chamissonis	Sand Ambrosia
Geobalanus oblongifolius	Gopher Apple
Grindelia humilis	Gum Plant
Guilandina bondoc	Nicker Vine
Guilandina crista	Nicker Vine
Haplopappus canus	Golden Bush
Helianthemum scoparium	Rush-rose
Helianthus debilis	Dune Sunflower
Heliotropium convolvulaceum	Heliotrope
Heliotropium curassavicum	Heliotrope
Heterotheca grandiflora	
Heterotheca subaxillaris	Golden Aster
Holcus lanatus	Velvet Grass
Hydrocotyle bonariensis	Seaside Pennywort
Hymenocallis keyensis	Key Spider-lily
Hymenocallis palmeri	Dune Spider-lily
Ipomoea per-caprae	Railroad Vine
Ipomoea spp.	Morning-glory
Ipomoea stolonifera	Beach Morning-glory
Iva frutescens	Marsh Elder
Iva imbricata	Marsh Elder
Jaumea carnosa	
Juncus longistylis	Coastal Rush
Juncus roemerianus	Needlerush
Lathyrus japonicus	Beach Pea
Lathyrus littoralis	Beach Pea
Lathyrus maritimus	Beach Pea
Lathyrus sylvestris	Flat Peavine
Lechea maritima	Pinweed
Lespedeza bicolor	
Lespedeza stipulacea	
Limonium carolinianum	Sea Lavender
Lippia nodiflora	Cape Weed
Lithospermum canescens	Puccoon
Lotus tenuis	Narrow Leaf Trefoil
Lupinus arboreus	Yellow Lupine
Lupinus chamissonis	Bush Lupine
Lupinus cumulicola	Sand Lupine
Lupinus littoralis	Seashore Lupine
Lupinus perennis	Wild Lupine

Table 9 (continued)

BOTANICAL NAME	COMMON NAME
Maytenus phyllanthoides	Guttapercha
Melilotus albus	
Melilotus officinalis	
Mesembryanthemum aequilaterale	Sea Fig
Mesembryanthemum crystallinum	Ice Plant
Monanthochloe litoralis	Key Grass
Muhlenbergia capillaris	Hari Grass
Nicotiana glauca	
Oenothera cheiranthifolia	Sand Primrose
Oenothera drummondii	Evening Primrose
Oenothera humifusa	Evening Primrose
Oenothera linearis	Sundrops
Oenothera mucronata	Sea Primrose
Panicum amarulum	Coastal Panic Grass
Panicum amarum	Dune Panic Grass
Panicum clandestinum	Deertongue Grass
Panicum portoricense	Panic Grass
Panicum virgatum	Switch Grass
Paspalum vaginatum	Salt Joint-grass
Phalaris arundinacea	Reed Canary Grass
Phalaris canariensis	
Phragmites communis	Reed Cane
Phytolacca americana	
Poa compressa	Canada Bluegrass
Poa macrantha	Seashore Bluegrass
Polygonum aviculare	Knotweed
Polygonum glaucum	Seaweed Knotgrass
Polygonum paronychia	Smartweed
Polygonum punctatum	
Polygonum tenue	Shore Knotweed
Polypremum procumbens	Dune Gentian
Pteridium aquilinum	Bracken Fern
Pteridium latiusculum	Bracken Fern
Remeria maritima	Beach Stars
Salicornia perennis	Glasswort
Salicornia virginica	Glasswort
Salsola kali	Saltwort
Setaria italica	Foxtail
Selaginella rupestris	Club Moss
Sesuvium maritimum	Sea-purslane
Silybum marianum	Milk Thistle
Smilax auriculata	Greenbriar
Smilax bona-nox	Bullbriar
Solanum dulcamara	Bitter Nightshade
Solidago sempervirens	Evergreen Goldenrod
Solidago sempervirens mexicana	Gulf Goldenrod

Table 9 (concluded)

BOTANICAL NAME	COMMON NAME
Sorghum halepenese	Means Grass
Sorghum vulqare	Sorghum
Spartina foliosa	Salt-marsh Grass
Spartina michauxiana	Slough Grass
Spartina patens	Salt-meadow Grass
Spartina townsendii	Cord Grass
Spartina juncea	Spanish Broom
Sporobolus domingensis	Rush Grass
Sporobolus virginicus	Rush Grass
Sporobolus wrighti	Bunch Grass
Stenotapharum secundatum	St. Augustine Grass
Stipa spartea	Porcupine Grass
Sueda linearis	Sea-blite
Sueda maritima	Sea-blite
Tournefortia gnaphalodes	Sea Lavendar
Tradescantia foliosa	Spiderwort
Trifolium procumbens	Hop Clover
Uniola paniculata	Sea Oats
Vicia villosa	Hairy Vetch
Vinca minor	Periwinkle
Vinca rosea	Periwinkle
Vitis cordifolia	Grape
Vitis labrusca	Grape
Vitis mustangensis	Muscadine Grape
Vitis rupestris	Sand Grape
Waltheria americana	Coast Chocolate
Wedelia trilobata	Wedgegrass
Xanthium pennsylvanicum	
Zoysia tenuifolia	Mascarin Grass

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